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The Edible Arracacha—*A Little-Known Root Crop of the Andes*[1]

Though a companion of the potato in Andean nativity and in food value to Andean aborigines, arracacha, for various reasons, has not been successfully introduced into other parts of the world, despite efforts to that end.

W. H. HODGE[2]

Introduction

"Unas raices hay tan gruesas como el brazo, e mas e menos, e muy semejantes en el sabor e olor e color a las zanahorias, salvo que no tienen aquella medula o tallo de en medio duro como la zanahoria sino todo este fructo o raiz se come muy bien . . . ."[3] Oviedo (20).

The information here recorded about a strange South American plant was given to the famed chronicler, Oviedo, by one Diego de Molina who had just come (1533) from New Castille (including modern Ecuador, Peru and Bolivia). Although unnamed by Molina, the Andean root crop here so well, even if briefly, described undoubtedly refers to the edible arracacha (*Arracacia xanthorrhiza* Bancroft (*Arracacia esculenta* DC.)).

Even though this plant approaches the potato in importance in some localities of the Andes, it required almost 300 years for it to be brought to the attention of taxonomists. Culture of the arracacha was mentioned briefly in 1805 (27), but it was not until 1825 that a scientific description was at last published[4]. Yet one may say to-day that, except in its area of cultivation, the edible arracacha is still almost as little known to horticulture as it was at the time of the Conquest[5]. Only in highland Colombia has the plant been rescued by agriculturists from the obscurity of an aboriginal crop and its culture been directed into rather intensive and valuable if local production.

What are the reasons for the arracacha's prolonged obscurity? For one thing, perhaps, the early professed resemblance of its roots to those of its umbelliferous cousin carrot (and parsnip), especially when cooked, have made many an otherwise interested scientist pass it by unnoticed. Then, too, in the Andean market-place its older roots, especially the main rootstock, may be mistaken in a superficial glance for roots of yuca (*Manihot*). Even if recognized, the arracacha would still have to run the gamut of prejudice which invariably surrounds anything new—including vegetables! Again, in

[1] Contribution from the Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils, and Agricultural Engineering, United States Department of Agriculture, Beltsville, Md. Photographs by the author unless credited otherwise.

[2] Principal Economic Botanist.

[3] ("There are certain roots as thick as the arm, and more or less and very similar in flavor and odour and colour to carrots save that they do not have that core or stem in the center as in the carrot, but all this fruit or root is eaten very well . . . .")

[4] By Bancroft in Trans. Agr. Hort. Soc. Jamaica, **1825:** 5. 1825.

[5] In a recent taxonomic paper, Constance (4) gives a provisional treatment to the ten South American species of the genus and emphasizes (p. 48) the relative paucity of information regarding the edible arracacha and especially concerning its domestication and origins.

the northern part of its range (Colombia and Venezuela), the highland tribes, to whom the arracacha was an important subsistence crop in many cases, have been decimated. This occurred centuries ago—shortly after the Conquest. Obviously ethnobotanical studies of such " lost " tribes were never made.

In the southern part of its range (Ecuador, Peru, Bolivia), the arracacha has been similarly overlooked, but perhaps for a different reason. There, in the old Inca area, the arracacha, although apparently widely grown, competes in popularity with a larger variety of domesticated highland crops, and its position, at least to-day, in the aboriginal agriculture, appears to be less important than in the north. One cause of such reduced popularity in Peru and Bolivia may be the dominance of high terrain (the altiplano or tierra fría) and the consequent agricultural need for cold-resistant crops, such as certain endemic types of potatoes and other strange tuber plants like the oca (*Oxalis tuberosa*) and ullucu (*Ullucus tuberosus*) [6]. Such terrain as is amendable to the growing of arracacha is found only in the more temperate inter-andean valleys (tierra templada) where, however, tillable land is at a premium. The cultivated highlands of Colombia are on an average lower, less cold and hence more temperate than similar areas in Peru and Bolivia. With a more congenial climate in the north, it is little wonder that it is there that the edible arracacha has prospered.

FIG. 1. A view in the Central Andes of Colombia near La Unión, Department of Antioquia. Elevation approximately 7500 feet. Arracachas are a prominent crop in the cultivated areas in the valley.

General Description of the Plant

This plant, grown in many parts of the Andes for so long, is a stout semi-

[6] For a discussion of these tuber-producing species, see reference (14).

Fig. 2. A typical arracacha plant in a garden near Bogotá, Colombia. Note how loose soil is kept hilled up around the plant to enable good root and tuber production.

caulescent herb, one of the largest of the cultivated umbellifers. Its coarse stems and leaves usually attain a height of about a meter. The inflorescences are typical of the family, the small flowers comprising them usually being purplish or yellow. They are seldom seen, for the crop—propagated by offsets—is harvested long before flowering occurs. For the same reasons, fruits are even rarer, and Constance (4) points out that truly mature fruits never have been described scientifically. Plants long-cultivated vegetatively often fail to set abundant fruits. The writer has made a special effort to locate fruiting material in the Central Cordillera of Colombia but without success; in fact, few growers admit having seen "seed". Nevertheless it must be produced, for there are several allusions to seed in the literature. Seed obtained by the British at Bogotá served to introduce the species into India in 1880, and about the same time seed from plants cultivated in Jamaica successfully established the arracacha in Ceylon (1). And in the United States seed was set by at least one plant grown at the old Plant Introduction Field Station at Brooksville, Florida, in November, 1918.

As a crop plant, arracacha somewhat resembles celery. This resemblance to celery has resulted in the application of the Spanish name "apio" (celery) to this plant in various parts of its natural range, particularly in the Venezuelan highlands and in Ecuador. In the arracacha it is not the aerial stems but the underground parts which are the important edible portions.

The edible subterranean portion of this species is a compound structure. Its primary portion consists of an often large, more or less cylindrical, cormose rootstock, indistinctly marked with a number of horizontal nodose rings. When sectioned this main rootstock, unlike the true roots that are produced from it laterally below, shows a central core. Being coarse in structure and rather strong in flavour, the rootstock, although widely eaten, is not preferred for culinary purposes. It is often fed to stock.

At maturity there arises from the base of the rootstock a ring-like aggregation of slender lateral roots clustered somewhat like those of dahlias or yucas (*Manihot*). There may be as many as ten of these smooth-skinned roots which in size and form, and in texture, colour and odour resemble parsnip roots. They may be compared also to the roots of carrots, as several authors have done (1, 15), but differ from them of course in colour as well as in the fact that these true roots of the arracacha possess a white or yellowish flesh which is homogeneous and without a central core-like cylinder, a point remarked upon long ago by Oviedo. Unlike the coarse main rootstock these lateral roots, growing from the base of the main rootstock, are very tender and delicate in flavour, and for these reasons they constitute the choicest source of the table vegetable.

Growing as thickened protuberances from the crown of the main rootstock of the arracacha are a number of shoots which arise from enveloping sheaths to form the aerial branches and leaves of the plant. Although the bases of these shoots are also underground and swollen with stored food, they are not generally utilized as food but instead serve as offsets for the vegetative propagation of this crop.

Horticultural Varieties

Three principal horticultural varieties apparently are known throughout the range of the species in the Andes. These differ from one another principally in the colour of the flesh of the roots: one is white (blanca), "like some radishes and turnips"; another is creamy yellow (amarilla) and probably accounts for

FIG. 3. *Arracacia xanthorrhiza* Bancroft, from a plate in Curtis's Botanical Magazine, 1831.

the specific name *xanthorrhiza*; while the third is called purple (morada), but it, too, is really white though possessing "a violet or mulberry-coloured ring around the insertion of the crown, or similarly coloured spots upon the widest parts".

The relative merits of each of these varieties was reported upon in 1861 by Diaz (7) who (in translation) wrote:

"The yellow is the most common and almost the only sort cultivated in many localities; it yields the largest crops, whether in numbers of roots or in their individual bulk. Of all the varieties the yellow is the most robust and resists best the inclemencies of the weather, but unfortunately it is also the tardiest grower".

"The white is much in demand amongst connoisseurs, as it possesses a more agreeable flavour, softer texture, and other culinary advantages; amongst the cultivators it is esteemed for its precocity, although it suffers more than the yellow when the meteorological conditions are not favourable, and its yield is always less as regards weight".

"The violet or mulberry-coloured (*morada*) appears to possess the same qualities as the white, and to resemble that variety very closely both with respect to its merit as an esculent and as regards its cultivation".

Culture

To-day the edible arracacha is commonly met with in the Andean highlands all the way from Venezuela to Bolivia. The plant is said to give some sort of yield at practically all elevations excepting the lowlands; but in Colombia, at least, its greatest production is made at altitudes between 1700 meters and 2500 meters where the temperature ranges from 15° to 20° C. throughout the year. Although in many parts of its range the arracacha was and still is an aboriginal crop, practically no information is available on the cultural practices developed for this plant by Andean Indians. Nevertheless, it may be assumed that the agricultural techniques now used by growers of arracacha in its present "heartland" in Colombia represent in general the practices originally evolved by and subsequently borrowed from aborigines and probably still in use wherever the crop is grown by such primitive peoples.

The arracacha in Antioquia, and probably generally elsewhere in its area of cultivation, is a crop rotated with the white potato. Maize often follows these two in the rotation or may be interplanted. Other crops are also often interplanted; these are usually leguminous and include varieties of beans and peas.

Over a century ago, Hooker (15) [and later Diaz (7)] summarized what then was known to him regarding arracacha culture in Colombia (e.g., Bogotá), and his account may be compared with the data which follow and which apply today to the important producing centers of the Central Cordillera of Colombia in Antioquia near the city of Medellín[7]. In that area the arracacha crop may be planted at any time of year, but in general planting occurs at the initiation of the rainy seasons (in April and in September) which may vary considerably elsewhere in the Andes. The species prefers a rich loose soil which permits full development of the lateral roots.

Propagation. As noted above, seed is apparently seldom formed. Its use considerably extends the time required to produce a crop, and so it is seldom utilized even when available. Propagation is thus entirely vegetative. The offsets or shoots, produced on the crown of the main rootstock, serve as propagules. Among Antioqueñan growers these offsets are called "colinos", while the cor-

[7] Certain of these data on present day arracacha culture in Colombia have been supplied by friends and former colleagues in Medellín, and the writer wishes to express thanks especially to Dr. Ernesto Arango, Agrónomo de la zona de Oriente de Antioquia; to Prof. F. Luis Gallego and Prof. Carlos Garcés O. of the Facultad Nacional de Agronomía.

FIG. 4. *Arracacia xanthorrhiza*, flowers and young fruits on a plant grown at Brooksville, Florida. Photograph taken November 19, 1918. (*B.P.I. photo*).

mose rootstock from which they spring is known as " cepa ". In Hooker's day the latter was called " madre " (mother), while the edible roots produced laterally below were termed " hijos " (sons).

Shoots intended to serve as propagules require a certain amount of preparation. Only that basal portion of the shoot actually possessing a bud with leaves is used. The stem which holds the bud is reduced to a section two or three cm. or late effective sprouting of the shoot but rather to insure that the young secondary roots (the edible ones), soon to form, are well distributed laterally on the new primary rootstock. Otherwise it is thought that these laterals would grow down vertically, crowding together with poor spacing and resultant stunting of growth. It is also customary to cut a cross-like mark on the slanted cut end of the offset, done " to get better spacing

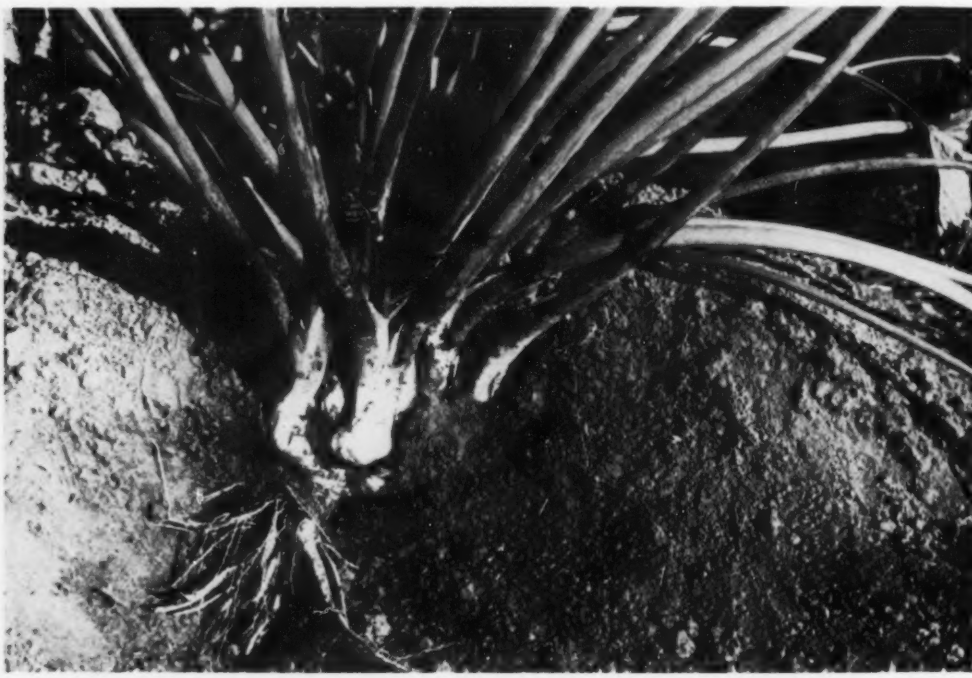

FIG. 5. An arracacha plant approximately three months from planting, Bogotá, Colombia. The banked soil has been partially removed to show the disposition of the leaf-bearing offshoots. At this age the main rootstock and lateral roots are still small.

so long. If not so trimmed down in length, it is believed that edible roots will not be formed from the new rootstock or cepa. At the same time all leaves are cut off ten to 20 cm. above their points of attachment to the stem, thus leaving short lengths of petioles as stubs on the propagule.

After the offset is detached from the rootstock at the time of harvest, its basal end is further severed with a slanting cut, given, it is said, not merely to stimu-

of the edible lateral roots ". After these several cuts are made, the offsets are set aside for two or three days to permit the cut surfaces to dry. Planting then proceeds.

Planting. As a crop plant, the arracacha is treated very similarly to potatoes with which it is often rotated. On a piece of land one cuadra in size (6400 square meters), 12,500 offsets are normally planted. Furrows are laid out a vara apart (836 mm., or approximately

one yard), after which holes are made for the plants. These are spaced approximately 60 cm. apart along the furrows. Fertilizer (either natural or artificial, or both) is first applied in each hole, and then the offsets, which may average about 15 cm. long, are set in so as to stand vertically one to a hole. Usually the propagule is placed in the ground with its basal portion covered and with the shoot slightly above ground. However, some Antioqueñan agriculturists are accustomed to cover the plantlet completely to a depth of two or three times its length. Following planting, the rows are mulched with trash, often that left over from the previous arracacha harvest. Such mulch may consist of corn stalks, weedy bracken fern (*Pteridium*), grasses or the like.

As the young plants grow, they are kept hilled up so as to afford ample loose soil in which the roots may develop. Two weedings generally are necessary, one at two months from planting and the other at five months. Because of the danger of harming the developing roots, these are hand weedings and must be done with care. Diaz (7) states that if, at three months after planting (he does not state whether this is from seed or from sets but probably the latter) the plants are tied up like endive, the shoots become blanched and can be employed as salad or can be stewed. In their homeland arracachas are quite free from disease and pests, only minor ones having been reported.

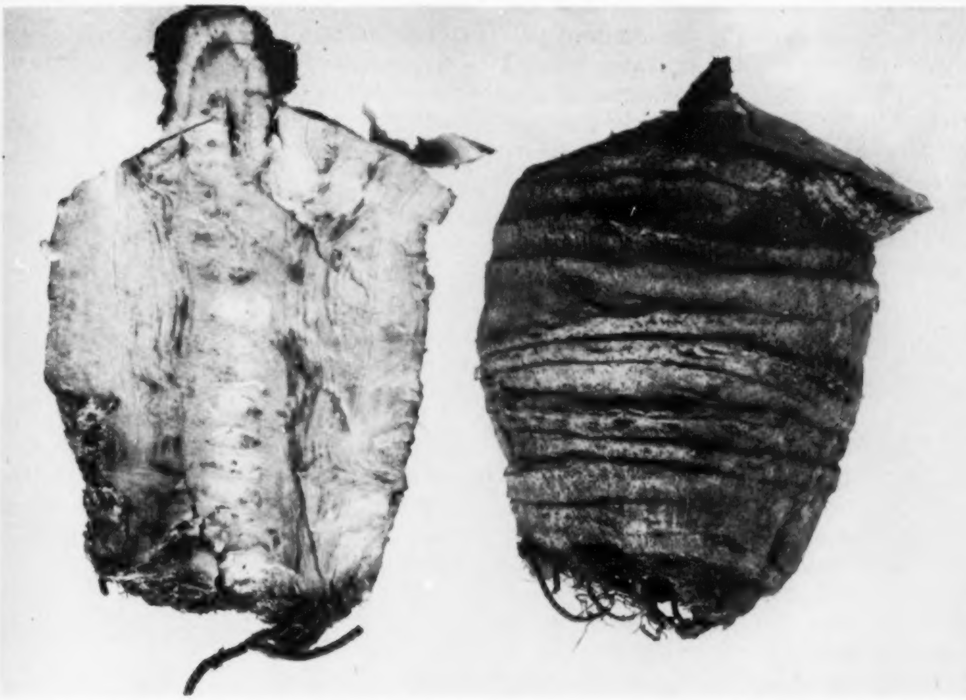

FIG. 6. The main rootstock (*cepa*) of an arracacha grown at Brooksville, Florida, in 1917. The sectioned portion at left indicates the coarse texture and central core which makes this organ of inferior quality for food.

Harvesting. Harvesting comes anywhere from ten to 14 months after planting, the time depending upon the variety planted. In the eastern part of Antioquia (Rionegro, La Ceja, etc.) only the white (blanca) and purplish (morada) forms

are grown, and of these the former is more popular among growers because it is preferred in the markets. Actually the young roots sometimes may be utilized at an age of eight months, but seldom are the plants permitted to remain unharvested after the roots mature, for the latter, if over-aged, toughen considerably and acquire a strong flavour—features which lower their value considerably as food. A sign that the crop is maturing is the concomitant yellowing and drying of the leaves as well as a cessation in the appearance of new shoots. A general custom amongst growers in Antioquia is to accelerate maturation in the final period of root development by breaking the petioles of the leaves ("quebrarles las hojas"), thereby virtually immobilizing the conductive system of the plant. This is accomplished either by twisting the petioles of the leaves or simply by doubling them, but in no instance are the leaves torn off. The skilled grower can tell when his root crop is ready for harvesting by snapping his finger on one of the young lateral roots. When properly mature, the sound (to him!) is unmistakable. Harvesting consists of completely pulling up the plants with the roots. All parts are fully utilized, though naturally the roots comprise the edible portion of the crop. At this time the offsets (colinos) are collected for the next planting, and all remaining plant debris is reserved either for forage or for future mulching.

Production. Although the arracacha is principally a staple of the countryfolk and so is grown largely on the small garden plots of individual families, there has been an increasing demand for these roots in the Colombian cities where, as in Medellín, industrialization has attracted arracacha-eating rural help for the factories. Around such cities there is considerable commercial production of this crop plant. Such production varies with the variety planted, the locality, the soil, and so forth, but typical harvests may range from 120 to 160 sacks per cuadra. In the Department of Antioquia the unit used in sales is the canasta (basket), of a size which holds on an average the roots of about a dozen plants. What the commercial grower will earn from the harvest of one cuadra of arracachas must of course be figured from his expenses. In 1948 the expenses involved in planting alone approximated those shown in the following table where the land was regular "potato soil". The figures are in Colombian pesos (one peso then equaled $0.58 U.S.):

Ploughing	30.00
Fertilizer (manure)	20.00
Fertilizer (artificial)	20.00
Labour	12.00
Cost of offsets (12,500)	50.00
Preparation of offsets	7.50
Planting	7.50
Mulching (including mulch)	200.00
Total	347.00

These production figures may be compared in a general way with some outdated ones, which, nevertheless, are the only other ones available. The latter were made at the Quinta Normal in Ambato, Ecuador, in 1917 (26):

Arracacha Test Planting (1917)
(Ambato, Ecuador)

Land	Good
Area	357 m.² (approx. $\frac{1}{11}$ acre)
Fertilizer employed	Sewage
Cultivation	In rows
Date of planting	May 11, 1916
Distance between plants	90 × 90 cm.
Number of plants on plot	335
Mortality	7%
Date of harvest	April 10, 1917
Weight of harvest	266 kilos
Actual value of production	$7.86 (Ecuadorian) equals $1.57 (U.S.)
Green forage (stems & leaves)	817 kilos
Production of roots per hectare	7,925 kilos
Value of production of roots per hectare	$234.17 (Ecuadorian) equals $46.82 (U.S.)

FIG. 7. Typical arracacha roots from the produce market at Medellín, Colombia. Note the relative proportions of the edible roots to the smaller and coarser rootstock (*cepa*) above, to which the roots are still attached. The roots resemble parsnips in form and color. They are without the coarse core that is found in the main rootstock.

In Ecuador the arracacha apparently is considered a supplementary crop to the white potato, taking its place in the markets when the potato harvest is poor. Moreover, the price of arracacha roots in the markets can be said to be in direct ratio to that of potatoes. For example, when a kilo of potatoes is worth ten cents, a kilo of arracacha roots costs four to six cents, depending upon the quality (26).

Utilization

To Andean aborigines, to-day as in the past, the roots of the arracacha, especially the tender lateral ones, are used primarily as constituents of the inevitable stews and thick soups which comprise the main fare in their daily diet. Aside from the primary nutritive value of the roots—the starch content runs up to 16% (22)—they offer an interesting taste variation to the subsistence diet of those Indians who were unfamiliar with such Old World crops as the carrot and parsnip.

The nomenclature of native stews may vary in the several Andean republics—for instance, " cocido " and " sancocho " in Colombia, " chupe " and " locro " in Peru—but, except for minor variations, the principal ingredients are the same and include the usual meat and vegetables. Colombian sancocho, a good example of such a stew, has become the standard dish of most countryfolk of the highlands. In a typical form of Antioquia, it includes, besides meat (stew meat or fowl), potato, arracacha, yuca, plantains and cabbage. The recipe of a favorite " picnic " cocido of Bogotá gives an idea of the important ingredients of a more complex stew in which the endemic South American vegetables (here italicized) represent what were perhaps the pre-Conquest components of an Indian stew:

2 pounds of salted beef (carne sesina)
½ pound of side of pork (tocino)
½ pound of pork sausage (longaniza)
½ pound of loin of pork
8 peeled *potatoes*
4 *arracachas*
3 *yucas*
3 cups of tender peas in their pods
2 cups *lima beans* without pods
2 plantains (platanos hartón, a species of *Musa*)
1 pound *cubios* (*Oxalis tuberosa*)
1 pound *ibias* (*Tropaeolum tuberosum*)
½ pound *chuguas* (*Ullucus tuberosus*)

Place meat in a large pot and cook in a small amount of water for about two hours. Then add the rest of the ingredients in layers on top of the heat and let simmer until tender, well covered.

The yuca and arracacha are to be peeled and quartered. The plantain is to be cooked separately in the skin. Peeled before serving.

The dish is served in separate platters. The meat all on one; potatoes, yuca, and arracacha on another; cubios, ibias, chuguas, peas, and lima beans on another; and the plantains on another.

Chopped onion, tomato and cheese, all heated in hot lard or butter is to be poured over all except the meat and plantains.

Arracacha roots are usually so tender as to require little cooking. Although generally served boiled in stews, they may be prepared in many of the forms in which potatoes may be eaten. The only preparation required is to scrape off the thin outer skin exactly as is done with carrots. Sliced in thin pieces they may be fried. Characteristic bunuelos, a kind of ball-shaped fritter made from the grated roots, are prepared by frying in deep fat. The starch apparently is very digestible and much less flatulent than potato starch, and so is used in the preparation of simple foods for very young children or for convalescents. Being cheap—a kilo of roots yielding 200–250 gms. of starch—it is also popular for laundry use. Mention has already been made of the use of the blanched young stems for salad or cooked greens. Pittier (22) even cites medicinal uses of arracacha in Vene-

FIG. 8. Offshoots as they appear on the crown of an arracacha plant. Such offshoots are used to propagate this crop. This specimen was grown in Florida and produced no edible roots below. (*B.P.I. photo*).

zuela: four to six teaspoons of the juice expressed from fresh roots, mixed with a little cooking salt, makes a mild purgative; also the same elaborated with bread-crumbs in the form of a poultice is used to alleviate the painfully swollen breasts of wet nurses or of recent mothers. An old remedy, mentioned in 1805 by Vargas (27), states that, " this root, reduced to a pulp enters in the composition of certain fermented liquors, supposed to be very proper to restore the lost tone of the stomach ".

Besides its primary use as a root vegetable by man, the arracacha plant is utilized as an excellent source of feed for his domestic animals. Both the roots (especially the coarser rootstock and the tuberous bases of the shoots) and the green foliage serve as fodder. Diaz (7) notes that the flavour of the plant apparently is exceedingly agreeable to animals and that they devour it with great relish. The same writer states further that arracacha is an especially valuable plant for use as feed in connection with the importation of foreign cattle. ". . . since in the transits from Honda to Bogotá (during which cattle formerly had to be driven from the hot low Magdalena river port of Honda up over high and arduous passes to the 2800 m. high Savannah of Bogotá—W.H.H.) it is the forage which they accept with the greatest avidity and that which enables them the soonest to recover from the poor condition in which they arrive. During the first months, whilst they are becoming acclimatized, the arracacha is almost the only food which will satisfy them, and they prefer it to green grass, hay, or any other forage ".

Origin and Early History of the Arracacha

Of the origin and early history of the arracacha, little or nothing is known. Nevertheless, the fact that this plant seldom sets viable seed perhaps points to long association with man, as does also the fact that the arracacha has never been seen growing under wild conditions (4). Cutler (6) reports having collected " escapes " above Sorata, Bolivia. These plants lacked tubers, but this is common in escapes, according to Cutler. Ulloa (26) also states that " Luis A. Martinez and other explorers have found it (arracacha) growing spontaneously in the temperate and moist forests of our Republic " (Ecuador), but this source is questionable. It is certain, however, that this species is a native of Andean South America and that it was brought into cultivation in the remote past by highland Indians in some part of the territory encompassed by its present range. But in just what part of this rather extensive area it first became intensively cultivated is impossible to ascertain from our present knowledge. Constance (4) suggests that the closest relatives of the edible arracacha may be the two species, *Arracacia equatorialis* Constance and *A. andina* Britton, one or the other of which is native to the highlands from southern Ecuador (Loja) to Bolivia. Thus systematic botany, although very tentatively, points to the Andean area south of Colombia as the original homeland of the arracacha. This particular part of the Andes comprises the old boundaries of the Inca civilization at its greatest extent. If one were to hazard a guess as to the origin of cultivated arracacha, one could hardly be condemned for suggesting that this civilization—(or rather its ancient forebears) attaining the highest degree of agricultural specialization in South America—first domesticated this root-crop.

Pre-Columbian Dispersal. At the time of the Conquest, the arracacha was in cultivation by the peoples of the Inca Empire. We know this from the chroniclers. Moreover, actual remains of its roots have been collected from ancient

FIG. 9. Offshoots as they are prepared for planting by the Indians of Sibundoy (Putumayo), Colombia. (*Courtesy R. E. Schultes*).

Peruvian tombs (24). And certain interesting diagrams on Nasca pottery, purported to be roots of yuca (30), might equally well be interpreted as representing the subterranean portion of arracacha with its primary rootstock and edible secondary roots.

The highlands of modern Colombia lie considerably beyond the old limits of the Inca realm, yet this area comprises the most important center of arracacha culture to-day. Whether the plant was brought into this region in distant pre-Columbian times or whether this region is actually the ancient homeland of this species is impossible to say. Unlike the old civilizations of Peru with their often remarkably preserved plant remains, those of Colombia are and probably always will be poorly known, at least as far as ethnobotanical materials are concerned. In the Colombian highlands around present-day Bogotá lived the only other important aboriginal group of agriculturists in South America. These were the Chibcha. Their civilization was virtually annihilated shortly after the Conquest, and the historical sources are therefore few and poor. The arracacha is merely mentioned as having been grown by this tribe (17). Another Indian group, the savage Pijao of south-central Colombia and contemporary with the Chibcha, were also early displaced or wiped out by the Spanish. They, too, are recorded as arracacha-growers (10). It appears, then, that *Arracacia xanthorrhiza* was being grown by these tribes at the time of the Conquest. Its dispersal as a cultigen throughout most of its present range in the Andes clearly came in pre-Columbian times.

Post-Columbian Dispersal. Post-Columbian arracacha history is equally fragmentary. Already noted is the fact that Oviedo in 1533, through his informant Diego de Molina, gave a succinct description of a kind of South American " carrot ". But not until 12 years later was the native name for these " carrots " discovered. In two letters from Peru (one dated 1545 and sent by one Juan Perez de Guevara; another dated 1549 and authored by Diego Palomino) the name " racacha " was first mentioned (30). According to Herrera (12), the word " racacha " is the Spanish form of the Quechua name, " r'accacha ", which is still used by the highland Indians of Peru. The name " arracacha ", in general usage in Colombia, appears to be of Peruvian origin. That the plant existed in the territory now called Ecuador was shown in 1573 when Juan de Salinas Loyola, replying to a royal questionnaire [8] in behalf of the district of Quito, wrote (in answer to question #65) (18): " siembrase en ella trigo, cebada, maiz, papas, y frisoles, arracachas, jicamas y camotes " (they plant in it (the soil) wheat, barley, maize, potatoes, and beans, arracachas, jicamas (*Pachyrrhyzus tuberosus*) and sweet potatoes). Wheat and barley from the Old World had already been introduced by the Spaniards. This is the sort of fragmentary information about the arracacha that occurs throughout the historical record. Finally, in a manuscript written in 1628–1629 and recently published (28), the Carmelite friar Antonio Vasquez de Espinosa reports " two kinds of arracacha " from the district of Cáceres (Antioquia) in Colombia.

Since the seventeenth century, sporadic mention of this crop has occurred here and there in the literature, but not until the days of Hooker in the nineteenth century was a more or less complete description of the plant and its culture drawn up. Most recent additions to our knowledge of the arracacha have been the brief paragraphs by Stur-

[8] A detailed questionnaire sent in 1569 by Juan de Ovando, minister of Philip II of Spain, to all local authorities in America. From the completed forms there was to have been compiled a great compendium on the Indies.

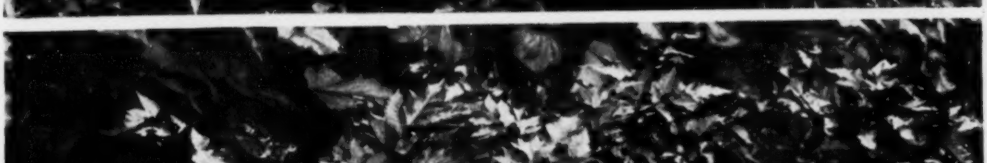

FIG. 10 (*Upper*). Arracachas interplanted with maize in an Indian garden at about 7000 feet elevation, Sibundoy, Colombia. (*Courtesy R. E. Schultes*).

FIG. 11 (*Lower*). Plants of *Arracacia xanthorrhiza* growing in a test plot at Yarrow, Maryland, in late October, 1919. (*B.P.I. photo*).

tevant (9), Cook & Collins (5) and Pittier (22), as well as a preliminary account by Hodge (13).

Present Range of Culture

The Arracacha in Its Native Andes. And what of the arracacha and its range of culture today? It is still grown, unchiefly as a crop of secondary importance, by widely separated Indian tribes in the Andes. But as to their methods of handling arracacha we still know next to nothing; in fact, for most of the contemporary groups of the highlands we have no observations whatever. According to Cutler (6), the arracacha reaches its southernmost limits of cultivation in the republic of Bolivia in the northern highland Departments (e.g., States) of La Paz and Cochabamba, where, cultivated by Quechua and Aymara Indians, it appears frequently as a vegetable in the community markets. In the markets of Sucre, to the south, it seems to be unknown. The three common horticultural varieties (blanca, amarilla, morada) are grown in Bolivia, and Quechua (and probably Aymara) names . . . equivalents in meaning to the Spanish . . . are used for these varieties. However, the three types of arracacha are not universally recognized in the various arra-

Fig. 12. Produce market of a highland village in Central Colombia (La Unión, Antioquia). Arracachas are usually available in such markets.

cacha-growing localities. Thus at Italaque (Province of Camacho) and near Sorata (Province of Larecaja) only the white and purple arracachas are known. The largest area under cultivation is at Sorata, but more varieties are recorded from Charasani (Province of Muñecas) where white, yellow and purplish types are grown and where Cutler wrote (6):

" We were guests of the prefecto in Charasani for several days and he apologized for having arracacha. It is often grown after potatoes although oca (*Oxalis tuberosa*) is preferred for this. The plants are grown in rows but not hilled up as high as potatoes or Oxalis. The plants grow quite high, about 75 cm., and have no apparent diseases while Oxalis and the potato have many diseases in the same area. (The variety) Morada is not a deep purple but only a faint color when cooked, with a darker ring about ¼ inch inside the outer surface when seen in cross section. There are occasional very dark tubers, and occasionally reddish purple ones, but these are not given any distinctive names. They are, however, color variants as marked as the morada but included in that group. Yellow is the least preferred (as in Antioquia, Colombia—W. H. H.) and those I tasted had a rougher texture and not as fine a flavor ".

Fig. 13. Vendor of arracachas in the Bogotá, Colombia, vegetable market. Only the coarser rootstocks are seen here. (*B.P.I. photo*).

At least five distinct forms thus occur in Bolivia to-day.

Arracacha is still valued by the Quechua of Peru who recognize and grow at least four varieties, called " R'umur'accacha ", " Arros-r'accacha ", " Huaisampilla " and " Morada " (12). In the lower part of the potato belt in Peru and Bolivia the arracacha replaces the hardier tubers, oca and ullucu, as the

species most frequently planted by the Quechua after potatoes in their normal program of crop rotation.

Scarcely half a dozen herbarium specimens (chiefly from the vicinity of Ambato and Loja) represent about all we know to-day about this plant in the predominantly Indian republic of Ecuador. Nevertheless, it must still be an important crop, for it occurs as a regular commodity in the markets, where it is called generally by the Spanish name " apio ". Ulloa (26) has given us a brief account of arracacha culture in Ambato. The need for ethnobotanical study in Ecuador is evident.

Colombia, on the other hand, can be called " arracacha-land ". The name " arracacha " even enters into provincialisms in the language of this republic (16). So widely cultivated is this plant to-day in that republic that on the basis of contemporary aboriginal use one might suspect this to be the ancient center of dispersal for the arracacha. For, besides the intensive nonaboriginal culture of this plant in Central Colombia (mentioned above), the arracacha is grown as a prominent secondary crop by indigenous tribes all the way from the Ecuadorean frontier to Venezuela and to the Caribbean coast close by Santa Marta. Of the Indian centers of the highlands, those in the south, in the general vicinity of Popayán and Pasto, are most important today. In the Central Cordillera of this area the Paez and Moguex tribes are cited as contemporary planters of arracacha (10), while the Sibundoy (or Quillacinga) of the eastern Cordillera in the upper reaches of the Putumayo recognize an unusually large number of horticultural forms of this plant—eleven in all. If the number of forms developed is to be considered as a criterion for locating the center of origin of a cultivated plant, then here is the arracacha's heartland. Not to be overlooked, however, is the notable lack of information for other tribes (of this and other regions) which may know an equal number of forms. It is sad to relate that this is apparently the only pertinent information on aboriginal arracacha culture north of Bolivia.

According to Schultes (25), in the valley of Sibundoy (Comisaría del Putumayo) at an elevation of 2225 meters, the local Sibundoy Indians often interplant their arracachas with maize. Their method of culture appears to follow generally that already described for the Department of Antioquia. It is significant that these Indians of Sibundoy have their own name for this plant. They call it " yengo ", not " arracacha ". It would be interesting to learn what other, if any, contemporary tribes of Colombia have native names for this species and what tribes know only the Quechua-derived name, " arracacha ". Horticultural forms recognized at Sibundoy include the following, the names of which are given here phonetically in their tongue (*Kamsá*) along with the Spanish equivalents:

Kamsá	Spanish
watjbtseng wats-ṣiyshá (one word)	amarillo morada
watjbtseng wabshajants-shá	blanco
waseléѕt moradshá	negra
wats-ṣiy wabajateshá	amarillo ceniciento
wats-ṣiy wachoros-shá	amarillo churoso
wabshajáns celést wabajateshá	lista blanca
wats-ṣiy celestshá	jojoa
wabshajáns wabajateshá	tallo ceniciento blanco
wats-ṣiyshá	amarillo
btsiyshá	arracacha grande
wabshajáns ketoquenseshá	algodón

The highland Indian cultures of central Colombia, as pointed out above, have long since disappeared, leaving the heritage of arracacha for the mestizo and Spanish populations which now inhabit this area. Only on the remote fringes of the highlands have some aborigines persisted, driven into isolation

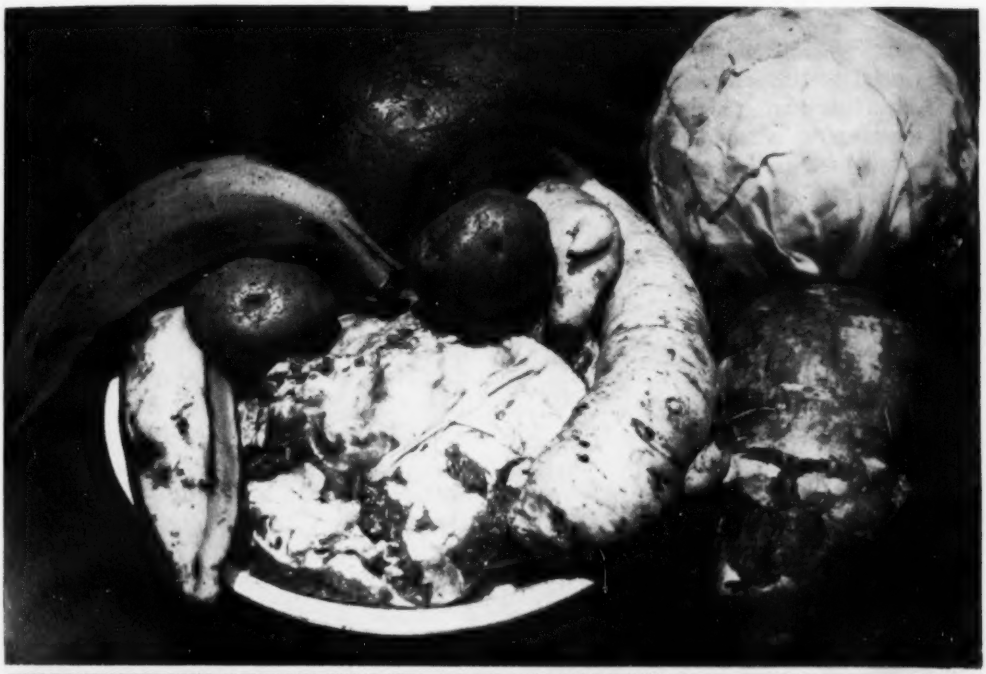

FIG. 14 (*Upper*). The raw materials for a typical Colombian stew (*sancocho*) shown here include stew meat, plantains, cabbage, potatoes, yuca, and arracacha (the parsnip-like roots). The avocado (at top) will be eaten fresh as a salad.

FIG. 15 (*Lower*). The stew (*sancocho*) prepared and ready to eat. A piece of boiled arracacha appears in the left foreground.

far from their original centers by the pressure of modern Spanish colonists. The Catío, of the Antioquia-Chocó borderlands, represents such a tribe which still cultivates arracacha (11). The name "pacucarrá" appears to be used by certain Indians of the Chocó (16). To the northeast of them, disjunct on the isolated mass of the lofty Sierra

FIG. 16. General range of arracacha as a crop plant in the Andes.

Nevada de Santa Marta, live primitive Chibchan-speaking peoples like the Cágaba to whom the arracacha is a principal subsistence crop (21). They possibly received this plant from the Chaké tribes inhabiting the Serranía de los Motilones, which is the only subhighland link between the main Andean mass near Ocana and the massif of Santa Marta. Only indirect evidence exists of the cultivation of arracacha by the Chaké; amongst plants listed (19) as cultivated by them and originating from the higher altitudes of the Andes is "celery"—certainly not Old World celery, but undoubtedly the arracacha which is known commonly throughout the Andes of Venezuela by the Spanish name for celery, "apio" (22), originally given because of the superficial resemblance of the foliage of these two related cultivated species.

Thus the arracacha can be seen to have spread to its ultimate limits in South America probably in pre-Columbian times. To the south, it could go no farther than the highlands of Bolivia at approximately 18° south latitude; in the north it has been carried to where the Andes disappear into the sea—in Colombia and in Venezuela. Dispersal in the latter country may have taken place in recent times (21). Had there been important agricultural peoples with regular and rapid means of intercourse between northwest Colombia and the highlands of western Panama, the arracacha might have gained a foothold as a cultivated plant amongst the highland tribes of Central America. But like the Andean white potato, which is also propagated vegetatively, the hot humid lowlands of tropical Panama—which would probably bring about quick deterioration of the vegetative propagules of plants of cool country—must have served as an effective barrier against successful passage of arracacha offsets into Middle America.

The Arracacha in Europe. One may wonder why an economic plant with the potential value of the arracacha has not been introduced permanently into higher temperate latitudes as has the potato. It has been introduced on several occasions but apparently without success. According to Sturtevant (9), all efforts to naturalize the plant in field culture in Europe met with failure. Introductions

were made in 1829 and in 1846, but wherever grown—in England, France and Switzerland—edible roots were not secured.

The Arracacha in the United States. The arracacha was first evaluated as a potential crop in the United States in 1825 " in New York ", and a few years later (1828–1829) it was planted near Baltimore. In both localities the crop was considered worthless (9). In 1916 planting stock was obtained from Caracas, Venezuela, by Fairchild, and during the years 1916–1920 trial plots of arracachas were established by the Department of Agriculture at the old Plant Introduction Field Station at Brooksville, Florida, and later at the Plant Introduction Garden at Savannah, Georgia.

The growth obtained in these locations has been described as fair to indifferent (2). As might be expected, the plants grew best during the cooler months of spring and fall (September and October) when temperatures were more like those characteristic of their Andean homeland. The heat of our southern summer appears to be inimical to normal growth. Observations at Savannah indicated that the arracacha throve best on heavier loamy soils which were usually moist but which did not become excessively saturated during the so-called rainy season. The plants were propagated by offsets much as is done in the Andes except that, in order to insure their reaching maturity, they were started in sand in a greenhouse and were then transplanted to the field as soon as all danger of frost was over.

It was found that the arracacha is definitely susceptible to nematodes. Since the plant is a long season crop, infestations become very bad by the end of the growing season and often are sufficiently severe to kill the plant or to so weaken it that the plant readily falls prey to rots. It appears that the arracacha cannot produce in this country except on nematode-free soil. Even then it is doubtful that it could become acclimated as a crop plant under the excessive summer temperature characteristic of the South.

FIG. 17. Pictograms from Nasca (Peru) pottery purported to be roots of yuca (*Manihot*). They might equally well be interpreted as representing arracachas (see Fig. 7). (*Illustration from Yacovleff and Herrera*).

A good series of photographs were taken of the plants grown at Brooksville. An examination of these, some of which are here reproduced, make it possible to comment further on the general trial of the arracacha as attempted in Florida. Of special interest is the photograph of inflorescences taken in mid-November of

Fig. 18. A two-year-old arracacha plant grown at Brooksville, Florida, as it appeared on November 16, 1918. A straw mulch protected the plant during the over-wintering period. The production of the choicer lateral roots was poor as compared with plants as grown in their native Andes (see Fig. 7). Nearly all growth was made in the coarse rootstock and in the tuberous offshoots on its crown. (*B.P.I. photo*).

1918, in which fruit is already setting. As mentioned earlier in this article, seed is seldom seen in arracacha plantings in the Andes, and no herbarium material bearing mature fruits has been available for study. Since plants at Brooksville set fruit it is evident that, when dug in December of the same year, they were fully mature. An examination of photographs of the freshly dug plants indicates that a very poor crop was realized compared to what may be expected in the Andes. The Florida plants produced an overabundance of offshoots from the crown of the plant and practically no lateral roots of edible quality below. Compare this with the situations in the Andes where the edible roots dominate the underground portions of the plant.

As to the edible quality of these United States-grown arracachas, not much is known save that they made, according to David Fairchild (**8**), a passable arracacha soup. It would be interesting to know whether the coarse rootstock and the strong-flavoured tuberous bases of the offsets were the parts of the plants sampled. Although these would be quite acceptable for the preparation of soup, their poor quality would serve probably to turn all but the most open-minded person against use of the arracacha in vegetable form. The pronouncement, after its nineteenth century introductions, that the crop was considered " worthless ", would make the writer suspect that the novice grower had not sampled the proper part of the arracacha's compound root system.

It is probably safe to say that the arracacha is unsuited as a temperate region crop. The fact that this plant is native to low latitudes where the photoperiods are short may mean that it cannot be grown with success much farther north than Florida or the Gulf States. More or less biennial it requires a long frost-free growing season. On the other hand the optimal growing temperatures (15–20° C.) for production of excellent quality arracacha roots are not to be found in the south but in the north. It is common knowledge in the Andes that arracachas grown at warm lower elevations, verging on the subtropical (thus equivalent to southern Florida), are of poor quality and insipid flavour. Conversely the best roots are produced in the cool temperate highlands (above

2000 m.). It would be interesting to see whether the arracacha could be brought to maturity in the northern United States. The long photoperiods and short seasons obtaining at such latitudes would probably preclude successful cul-

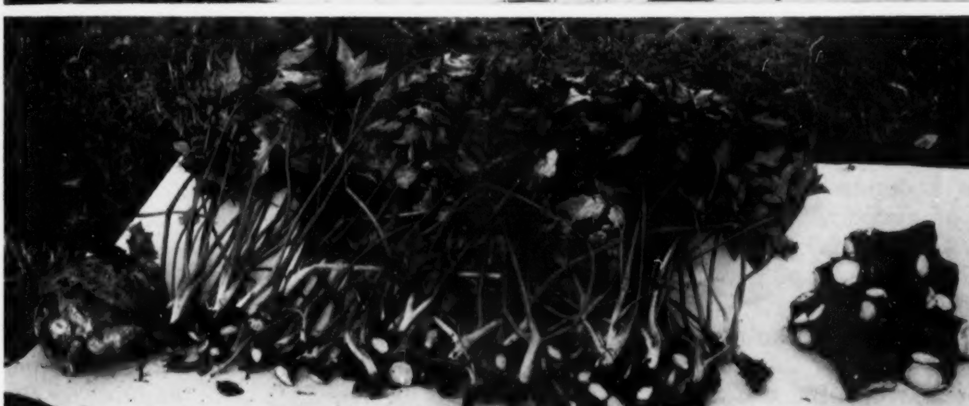

FIG. 19 (*Upper*). A clump of arracacha grown at Brooksville, Florida, in 1918. The plant was harvested in mid-November after two seasons growth. At the left is the main rootstock; on the right, the heavy tuberous offshoots, detached from the crown. As can be noted, production of edible roots on the lower end of the rootstock was very poor. Most of the underground growth was of coarse quality and hardly suitable for human consumption. (*B.P.I. photo*).

FIG. 20 (*Lower*). The same arracacha clump but with 55 propagation "sets" cut from the 13 tubers at the right. (*B.P.I. photo*).

ture. A solution might lie in careful selection of the best varieties from the northernmost or southernmost fringes (e.g., the highest latitudes) of the arracacha's natural range.

The Arracacha in the Caribbean Area. *Arracacia xanthorrhiza* has been successfully introduced into other highland parts of the tropics. In the New World it was carried early by the British from Colombia to Jamaica (the source of the type material of this species, obtained by Bancroft), and possibly it is still grown to some extent on that island. Later it migrated to Puerto Rico where in 1903 it was reported as growing extensively "in the mountains behind Ponce" (5). It is still found on the latter island where it is known as "apio". According to Winters (29), it may be seen mostly in the small plots which constitute the home gardens of the

people living in the central and eastern mountains of Puerto Rico. Cultivation in Puerto Rico is not particularly systematic. When a plant is harvested for food the top is cut off and replanted in some vacant spot in the garden.

Besides noting arracachas during his travels in Andean South America, Vasquez de Espinosa visited the Valley of Mexico where he recorded that " they have arracachas " (28). Sturtevant (9) likewise states that " the plant is also found in the mountain regions of Central America ". Although several other wild species of the genus occur in this area, it is probable that *Arracacia xanthorrhiza* was not known in Middle America in the 17th century. Certainly it appears to be unknown in Mexico to-day, and there is not any record of herbarium material of this species from Central America. However, by the time of Sturtevant it seems to have been introduced more than once into the highlands of Costa Rica and Guatemala. Wilson Popenoe, who is familiar with the plant as it occurs in the Andes, writes (23): " Many years ago I brought some roots from Jamaica . . . and planted them in Guatemala, at Antigua. It might have spread to a few other places from there and of course I do not claim my introduction is the only one which has ever been made. But it certainly is not to be listed as one of the food plants of Guatemala . . . I also have a picture (BPI photo #17843—W.H.H.) of a Costa Rican laborer holding up a plant of this species. I think it was (taken) somewhere above San José (actually at San Geronimo—W.H.H.), in the region of Irazú ". It is also grown commonly in the Chiriquí region on the Costa Rica–Panama frontier. At the present time the only important Central American center of arracacha culture is on the Costa Rica–Panama frontier in the Highland zone around Chiriquí Volcano. This area possesses fine agricultural soils which were worked by aboriginal tribes in pre-Conquest days. Because of the relatively short distance from Colombia it may be that the arracacha was carried to the Chiriquí Highlands in pre-Columbian time.

Thus, besides its cultivation in the Andes, the arracacha is known, though very locally, from the highland areas of Jamaica, Puerto Rico, Costa Rica and Guatemala. Apparently a lowland form has also been successfully established at Campinas, Brazil.

The Arracacha in the Old World Tropics. The British introduced arracacha into their colonies in the Old World tropics during the last quarter of the 19th century, and reports made at the time indicate that the species grew successfully in certain hill districts of India as well as in Ceylon (1). What the status of the plant is there to-day is unknown, but the Report of the Director of the Botanical Gardens in Ceylon for 1886 had this to say: " The arracacha is not generally liked by Europeans (though some like it), but much enjoyed by all the natives who taste it ".

Claes (3) has recently commended the arracacha's introduction to Africa, especially to the Belgian Congo, " or other warm colonies ", believing it might succeed where cultivation of the white potato has failed. This is doubtful for the arracacha has ecological demands very similar to those of the temperate-loving potato. On the other hand, throughout the cool highlands of East Africa, and possibly even on parts of the Drakensberg of South Africa, this Andean crop might prove a worthwhile introduction.

Wherever—outside of its native South America—it might be successfully established, the arracacha would still run up against the perennial " bogey " of a new food crop. The taste " likes " and " dislikes " of most people are ultra-conservative. Someone has said that it requires a hundred years for even a first-

class new crop to be generally accepted. Witness the time needed to bring the tomato and even the potato into their own. The arracacha is certainly not another potato, but the fact remains that the arracacha, in certain of its varieties and when properly grown and utilized, is an excellent root vegetable. For this reason arracacha culture merits more attention, especially in the cool tropical highlands of the world. Agriculturists might consider the words of David Fairchild who has stated with conviction: " I consider it (the arracacha) much superior to carrots ". One could add that thousands of inhabitants of the Andes would agree with him!

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Botanical Aspects of Oregano

The condiment name "oregano" should be understood to refer, not to any one species but to a particular spice flavor, furnished by plants of several genera in different parts of the world. About one-half of the amount used in the United States comes chiefly from Mexico as dried leaves and flowers of Lippia graveolens; the rest from several species of Origanum in several European countries.

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Oregano is a savory herb introduced into the United States by immigrants from the Mediterranean area and Latin America. As recently as 30 years ago this spice was little known to the average American (1). Since that time, particularly during the last ten years, oregano has become a familiar item on the grocer's shelf. Today it can be considered as one of our more important spices. In a recent article (17) it was included among the 12 most popular herbs in America, and its popularity is still increasing.

For a long time herb fanciers and others interested in spices have been trying to determine the exact botanical identity of the plant that is imported and marketed as oregano in the United States. Although other spices have long been known to be obtained from some particular plant species, oregano has not hitherto been correctly identified botanically. There has been great uncertainty and confusion regarding the species involved.

Recent books and articles on growing herbs for the home garden, on using herbs in cooking, and advertisements from several leading spice companies express the opinion that oregano is derived from some species of the mint family (Labiatae), often specifying *Origanum vulgare* L. or one of its varieties (12, 14, 20, 22, 26, 33). In spite of the statements that oregano is a species of the Labiatae, many of the authors of the above mentioned articles add that they are unable to identify any single recognized species of the mint family as the source of oregano. Few of them apparently have been entirely satisfied in assigning all commercial oregano to *Origanum vulgare*.

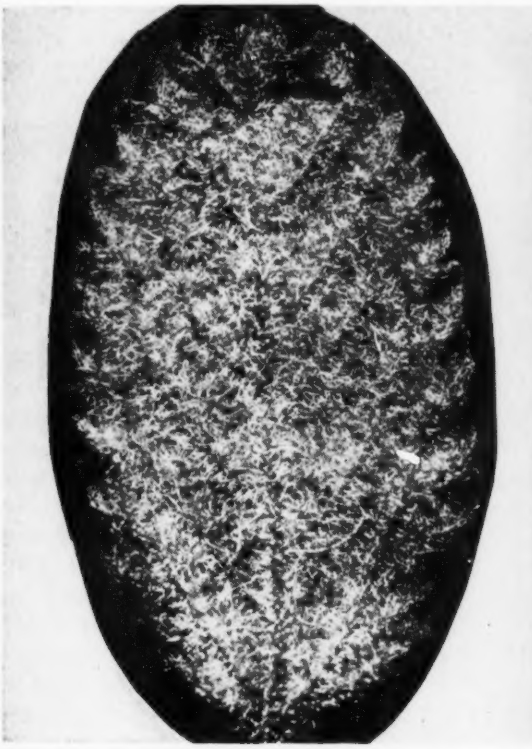
In order to clarify the taxonomic position of this spice the writer has approached the problem from two points of view. The first deals with an examination of the plant material itself. It was thought that this procedure might possibly identify the oregano material as some recognized species when compared with herbarium specimens. The second approach was to examine the literature dealing with the flora of those countries where oregano occurs. This was done in the hope of finding oregano described in such terms as would give a clue to its botanical identity.

Evidence from Plant Material

Evidence from plant material showed that at least two main types of oregano, Mexican and European, are being sold on the market. Spice dealers and statistics (11) from the United States Department of Commerce state that Mexico dominates the scene as an exporter of oregano. The United States receives anywhere from one-third to one-half of

its entire supply of this spice from Mexico. The rest comes primarily from Europe, with Italy, Greece and Portugal the more important exporters. Smaller amounts of oregano reach us from the Dominican Republic and Puerto Rico.

Mexican Oregano. Personnel of certain spice companies have offered valuable information as to the botanical source of Mexican oregano. A staff member * of a local spice and drug company had, previous to our meeting in 1952, noticed that the Mexican oregano differs somewhat from the European material. He had taken leaf samples to the Gray Herbarium of Harvard University, and with the assistance of some of the staff he had found the Mexican plant to be *Lippia Palmeri* Wats. Shortly after this discovery the writer obtained a large number of oregano samples from dealers in the Boston area. These samples were also compared with herbarium specimens at the Gray Herbarium. Most of the oregano from Mexico when checked as to leaf and floral structure was identified as *Lippia graveolens* H.B.K. Some of the older herbarium sheets of this species are labeled *Lippia Berlandieri* Schauer. Recently, however, these two specific names were brought into synonymy (**29**). The former name, *L. graveolens*, has priority and will be the



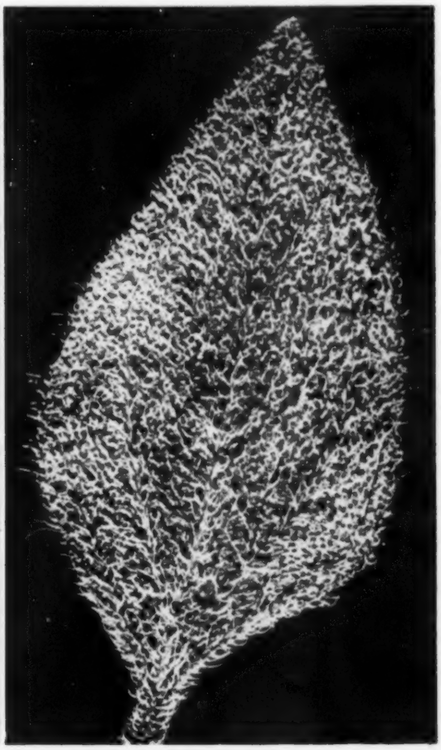


Fig. 1 (*Left*). Photomicrograph of a leaf of Mexican oregano (*Lippia graveolens*). Note the crenate leaf margin and the hirsute condition of the leaf.

Fig. 2 (*Right*). Photomicrograph of a leaf of European oregano (*Origanum* sp.). Note the entire leaf margin and the epidermal glands which appear as dark round objects in the photograph.

* Mr. Cyril Wetherall of the G. S. Cheney Company.

one used in this paper. The few remaining Mexican samples proved to be *Lippia Palmeri*. Thus all of the Mexican oregano which this writer has been able to examine has, without exception, proved to be of the genus *Lippia*, primarily *L. graveolens* but occasionally *L. Palmeri*. A sample imported from Puerto Rico and bought in a New York grocery also turned out to be a species of *Lippia*.

The interesting point to note here is that the genus *Lippia* is in the family Verbenaceae. It has been assumed all along in the herb literature that whatever species it might turn out to be, oregano was without question a member of the Labiatae. Now, however, we know that the plant most used in the United States as oregano belongs to another family, somewhat closely related to the Labiatae but nevertheless distinct from it.

European Oregano. Every sample of oregano imported from Europe and obtained by the author in the Boston area has been identified as belonging to the genus *Origanum*.

It has been generally assumed that oregano is derived from *Origanum vulgare* (commonly called wild marjoram). This assumption led to several attempts by the author and other writers (12) to use the naturalized plants of this species growing in the United States as a source of oregano. When this was done it was found that the dried American plants lacked the rich flavor of the commercial product. Local *O. vulgare* had a faint sweet odor, while the European oregano had a strong piquant aroma. This evidence seems to indicate that the *O. vulgare* growing in the United States cannot be used as a source of oregano. If this is true, then what *Origanum* species is being used as oregano? In order to answer this question a study was made of the leaves of European oregano. Using a dissecting microscope (approximately 15 power), it was found that the leaves of the European oregano have numerous prominent epidermal glands that appear as glistening golden droplets, round in outline. These prominent glands are a feature common to all samples of European oregano that have been observed. The American plants of *O. vulgare* that were examined had fewer glands on their leaves. These glands were poorly developed and inconspicuous, having little or no volatile oil in them, whereas the prominent glistening glands of the European oregano were gorged with oil (most of the volatile oils that give the characteristic flavor to the plant are found in these glands).

The leaves of *O. vulgare* and those of commercial European oregano are similar except for their epidermal glands, as described above. The difference in the leaf glands may explain why certain *Origanum* species may be used as oregano, while other species cannot be so used. The herbarium specimens at the Gray Herbarium were examined to see whether there are any species of *Origanum* whose epidermal glands match those of the commercial European oregano. All specimens labelled *O. vulgare*, whether collected in Europe, Asia or North America, showed poorly developed leaf glands, thus indicating that this species is not being used as oregano. Another group of *Origanum* species, however, possessed leaves which matched those of the commercial European oregano in every respect, including the epidermal glands. These species were labelled as follows: *Origanum gracile* L., *O. glandulosum* Desf., *O. hirtum* Link., *O. smyrnicum* L. (In recent years (1, 16) *O. hirtum* has been considered to be synonymous with *O. vulgare* and is quite possibly a variant of it.)

On the basis of leaf anatomy it is possible that one or more of the above listed species of *Origanum* are being marketed as European oregano. Among the forms of *O. vulgare* that were observed, only the one that was formally designated as *O. hirtum* corresponds ex-

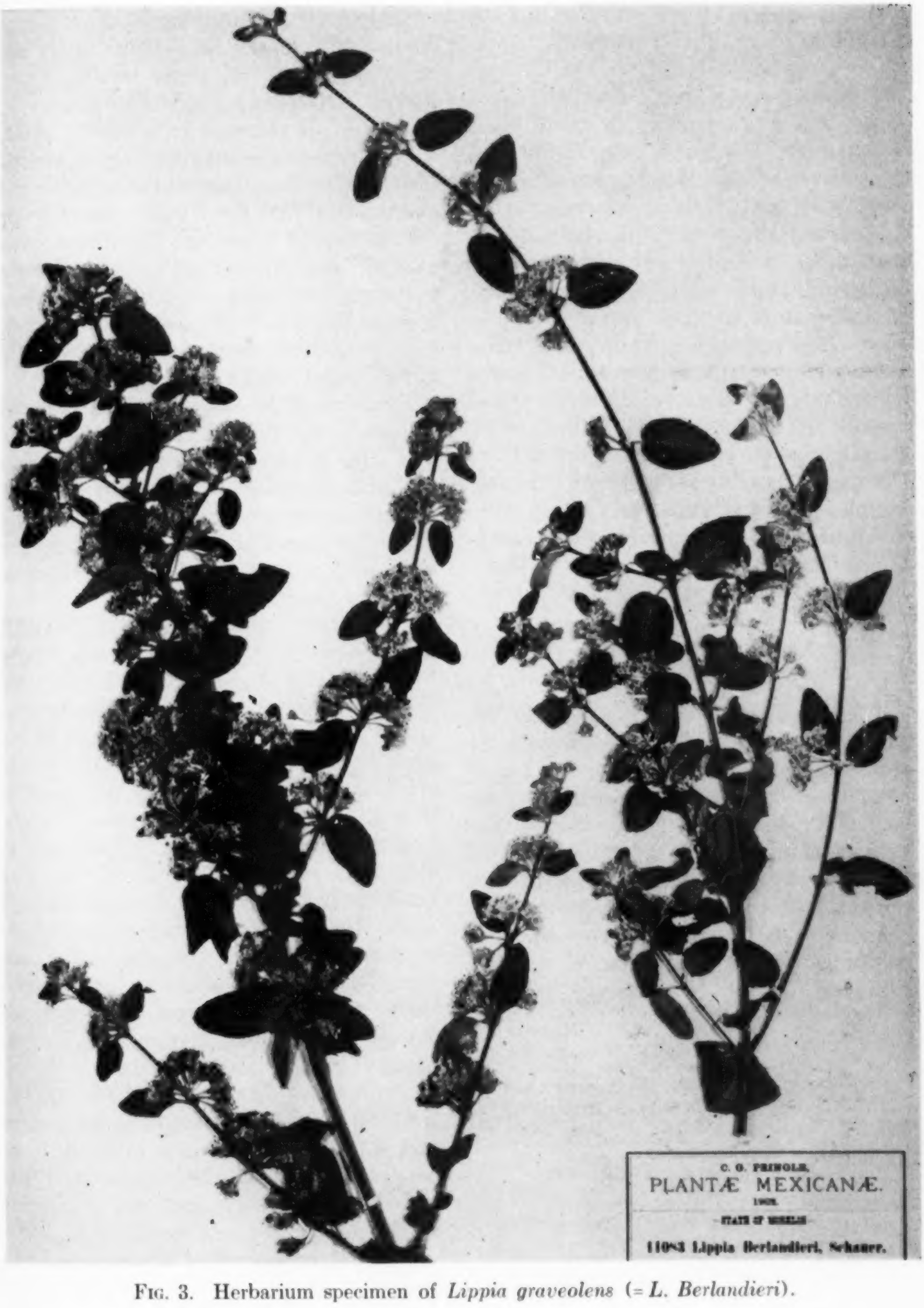


FIG. 3. Herbarium specimen of *Lippia graveolens* (= *L. Berlandieri*).

actly to the European oregano being sold. It is clear, therefore, that not all individual plants of *O. vulgare* are necessarily oregano.

The four species of *Origanum* listed above are quite similar in their gross morphology. Thus it is very likely that the natives of the Mediterranean countries, who gather the oregano growing wild along the rocky hillsides and in open fields, will pick any of the species indiscriminately simply because they have the right general appearance and odor. It is almost a certainty that shipments of European oregano to this country include one or more of these species. Species of *Origanum* other than those listed above may also be imported from Europe and sold as oregano. A few samples imported from Syria which were obtained in a Boston grocery were identified as *Origanum syriacum* L. [= *O. Maru* L. = *Marjorana Maru* (L.) Briquet (16)].

Distinguishing the Main Types of Oregano

The two main types of oregano on the American market, the Mexican material derived from *Lippia* spp. and the European from several *Origanum* spp., may be readily distinguished by examination with a hand lens of about ten power. The two types are quite distinct in certain leaf characteristics—pubescence (hairiness), presence or absence of large epidermal glands, and type of margin:

	Mexican Oregano (*Lippia* spp.)	European Oregano (*Origanum* spp.)
Pubescence:	Hirsute to densely hirsute with long coarse hairs	Sparsely hirsute with fairly long hairs
Large epidermal glands:	Absent (only minute glands present)	Present
Leaf margin:	Crenate	Entire or almost so

(These characteristics are shown in the accompanying photographs of leaves.) The minute glands in *Lippia* leaves are about ⅕ the size of those on *Origanum* leaves and quite different in aspect in that they are elevated on a minute stalk.

In order to distinguish *Lippia graveolens* from *L. Palmeri* the following characters have been used: the former species has at least eight lobes on each side of the leaf, and the flower peduncle is longer than the leaf petiole; the latter species has less than eight lobes on each side of the leaf, and its flower peduncle is not longer than the leaf petiole.

Evidence from Botanical Literature. A search was made through the floras and other botanical literature pertaining to Latin America, Europe and parts of Asia to determine in which countries the name "oregano" and its derivatives are used and with what botanical species they are associated.

"Oregano" is a vernacular Spanish name derived from the Greek roots "horos" and "ganos", and may be translated as "delight of the mountains" (23). Use of the name is widespread. It is found throughout the Western Hemisphere (5, 7, 8, 10, 37, 38, 42). It is known in Europe (9), the Middle East (3) and in parts of Africa, and is also used in certain areas of the Far East, for instance, the Philippine Islands (24). In general we can say that wherever the cultures of the southern European nations have made an impression, there we will hear some mention of "oregano" or local derivatives of this name.

Throughout the world there are at least 39 species, representing 16 genera and 6 families, which are being used as condiments or as medicinals and are called "oregano" or by some variation of this name.

Table I represents a summary of the use of "oregano" in the floras. The specific names are listed just as they were found in the original references.

Fig. 4. Herbarium specimen of *Lippia Palmeri*.

TABLE I. SPECIES REFERRED TO IN BOTANICAL LITERATURE AS "OREGANO", SOMETIMES SPELLED "OREGENO", "ORIGANO" OR "ORAGANO"

Coleus amboinicus Lour. (12)
Hedeoma floribunda Standl. (13)
Hedeoma patens Jones (13)
Hyptis albida H.B.K. (5)
Hyptis americana (Aubl.) Urb. (*H. gonocephala* Gris.) (7, 35)
Hyptis capitata Jacq. (31)
Hyptis suaveolens (L.) Poit. (31)
Lantana involucrata L. (5)
Lantana purpurea (Jacq.) Benth. & Hook. (*Lippia purpurea* Jacq.) (5, 37)
Lantana trifolia L. (28)
Limnophila stolonifera (Blanco) Merr. (24)
Lippia affinis Schau. (27)
Lippia Berlandieri Schau. (5, 37, 39, 42)
Lippia formosa T. S. Brandeg. (30)
Lippia Geisseana (R. A. Phil.) Soler. (28)
Lippia graveolens H.B.K. (28, 39, 40)
Lippia micromera Schau. (30)
Lippia micromera var. *Helleri* (Britton) Moldenke (28)
Lippia origanoides H.B.K. (30)
Lippia Palmeri Wats. (5, 13, 30, 39)
Lippia Palmeri var. *spicata* Rose (30, 37)
Monarda austromontana Epling (13)
Ocimum Basilicum L. (32)
Origanum vulgare L. (3, 5, 9, 17, 19, 35, 38)
Origanum Majorana L. (5, 35)
Poliomintha longiflora Gray (5)
Salvia sp. (5)

Other forms of "oregano" in botanical literature.

Oreganillo
Lippia cardiostegia Benth. (30)
Lippia graveolens H.B.K. (30)
Lippia myriocephala Schlecht. & Cham. (30)
Lippia umbellata Cav. (30, 39)
Oreganillo del monte
Lantana hirsuta Mart. et Gall. (18)
Oreganos
Borreria spp. (35)
Orenga
Origanum vulgare L. (9)
Origan
Origanum vulgare L. (3)
Oregano brujo
Coleus amboinicus Lour. (32)
Coleus aromaticus Benth. (8)
Oregano cabruno
Satureja Thymbra L. (9, 19)
Oregano cimarron
Hyptis suaveolens (L.) Poit. and other *Hyptus spp.* (7, 36)
Lippia graveolens H.B.K. (27)
Oregano de Cartagena
Coleus amboinicus Lour. (21, 36)
Eryngium foetidum L. (21)
Oregano de Espana
Coleus amboinicus Lour. (31, 32, 36)
Coleus aromaticus Benth. (8)
Origanum vulgare L. (31)
Oregano Frances
Coleus amboinicus Lour. (21, 36)
Oregano del pais
Lippia Helleri Britton (32)
Lippia micromera Schau. (8)
Lippia origanoides H.B.K. (5)
Oregano del campo
Coleosanthus veronicaefolius H.B.K. (5)
Oregano del cerro
Coleosanthus veronicaefolius H.B.K. (5, 39)
Oregano del monte
Coleosanthus veronicaefolius H.B.K. (5)
Oregano de la sierra
Calamintha potosina Schaf. (5)
Oregano montes
Lippia cardiostegia Benth. (27)
Lippia umbellata Cav. (39)
Oregano poleo
Lippia micromera Schau. (31)
Oregano silvestre
Lantana glandulosissima Hayek (27)
Oregano verde
Origanum virens Hoffm. (19)
Oregano xiu
Lantana citrosa (Small) Moldenke (27)
Lantana glandulosissima Hayek (27)
Lantana velutina Mart. & Gal. (27)

Some of these species may have undergone nomenclatorial changes in more recent years, as, for example, in the case of *Lippia Berlandieri* and *L. graveolens* mentioned previously.

Historical Evidence. In examining the history of oregano it can be seen how it came to include such a considerable number of widely divergent species. The earliest use of this herb takes us back to the ancient civilizations bordering the Mediterranean Sea. Theophrastus (380–287 B.C.), in his classic work "Enquiry Into Plants" (43), used the terms "origanos" and "origanon". From his discussion of the plants it is believed that he was describing species of *Origanum*, a genus native to the Mediterranean region. References to this spice are also

FIG. 5. Herbarium specimen of *Origanum glandulosum*.

found in the writings of the Roman naturalist, Pliny (I Century A.D.), and of the Greek, Dioscorides, the father of economic botany (I Century A.D.). There is no reason to believe that any plants other than those belonging to the genus *Origanum* were used as oregano until the 16th century. At that time European explorers and settlers began colonizing distant lands in Asia, Africa and the New World. There is evidence in the Spanish chronicles of this latter period that the colonists began using some of the plants, that they found growing in these areas, as oregano. Hernandez (18), who travelled in Mexico from 1571 to 1577, mentions a plant called " Oreganillo del monte " (*Lantana hirsuta* Mart. et Gall.) in Oaxaca. Cobo (6), when describing his travels in Mexico in the early 1600's gave an account of a strange plant whose aroma reminded him of the oregano that he knew back in Spain. The following is a translation: " On the southern coast of Mexico there grows a shrub very similar in odor to oregano. It has many straight branches full of large leaves four fingers long and about two wide, somewhat similar to those of the chestnut. I saw them (the plants) while walking through that land, and the odor they gave off was so strong that it seemed as if I were walking through a field of Oregano ". From these accounts it is easy to understand how, as time went on, more and more species outside the genus *Origanum* began to be included under the name oregano on the basis of their similar odor and flavor.

Discussion

In modern books on the floras of various Latin American countries, species of *Origanum* are rarely mentioned, except occasionally as being cultivated in local gardens, but never as growing wild (5, 34, 35, 38). References to species of *Lippia*, on the other hand, are frequent. These species are native to the warmer areas of this hemisphere and Africa. The lippias are more commonly called " oregano " than any other plants. Standley (42) observes that oregano (*Lippia* spp.) is sold in the stores and markets in almost all parts of Mexico. Roig y Mesa (36) note that an oregano (*Hyptis* spp.) in Cuba is different from the European variety. Rose (37) mentions that the leaves of oregano (*Lippia* spp.) are very much used in Mexico to flavor food. He continues, " The name oregano seems to be a generic name applied to the leaves thus used of several species of *Lippia*. The plant so called at Acapulco is *L. Berlandieri*, in Lower California *L. Palmeri spicata*, while on the table-land I found it to be *L. purpurea* " (later renamed *Lantana purpurea*). In a recent flora of Costa Rica (41) a form of *Lippia* is designated as oregano, while again no mention is made of *Origanum* as a genus.

According to this evidence in the floras we should expect the oregano which is imported from Latin America to be some plant other than belonging to *Origanum*, and such is the case, as has already been pointed out in the discussion under Mexican oregano. We thus have two independent paths of evidence leading to the same conclusion.

Reference to the botanical literature makes it evident that if we were to ask for oregano in various parts of the world, what we would receive (if anything) would depend on where we were at the moment. In Europe or the Near East, for example, we would receive some *Origanum* species (3, 9, 19). In the Far East we would be likely to obtain *Coleus amboinicus* (4, 25) or *Limnophila stolonifera* (24). In Mexico or Central America we would probably receive some form of *Lippia* (39), *Lantana* (37) or perhaps *Hyptis* (5); in the West Indies, *Hyptis* (31) or *Coleus* (8, 21). Last year, while travelling in Cuba, the author secured several plants which were

used as a condiment and called "oregano" by the local populace in the vicinity of Cienfuegos. The plants have been identified as *Coleus amboinicus* of the family Labiatae.

Because of its diverse usage all over the world, our problem is to redefine the name "oregano" in the light of the facts presented above. The solution is that "oregano" should be applied to a number of different plant species, all having in common a particular herb flavor. Oregano should not be thought of as coming only from a single species of plant. In other words any herbaceous plant whose leaves and flowering parts are used as a condiment can be included in this definition provided the plant has that aroma and flavor which we recognize as being oregano. This concept seems to fit the facts. It must be noted, however, that the herb flavor is not definable other than by personal experience with it, and that there is a small amount of variation between the different types of oregano. This is due in all probability to minor differences in the essential oils present. Analyses of the volatile oils of only two oregano species was found in the literature; *Coleus amboinicus* (4) and *Origanum vulgare* (15). In both cases a major component of the oils in the leaves was carvacol. Whether or not this compound is mainly responsible for the distinctive oregano flavor is not known. This question deserves more attention.

Can Oregano Be Grown in the United States?

Because of its increasing popularity in this country more people than ever are now learning to use and enjoy oregano on meat, fish and poultry dishes, and with vegetables and sauces. It is only natural that persons with herb gardens should be interested in raising their own oregano. The geographical ranges of all oregano plants except *Origanum* spp. lie in the tropics or in the

FIG. 6. Herbarium specimen of *Origanum vulgare*.

warm temperate regions. *Lippia graveolens* and *L. Palmeri,* for example, are found growing wild only as far north as Texas and New Mexico. Undoubtedly they and other species listed in Table I could be cultivated in other areas of the southern and southwestern United States.

Whether or not we can grow oregano in the northern United States depends on the ability of the former *Origanum hirtum* and some of the other *Origanum* species with prominent epidermal glands to withstand our climate. All the specimens of these perennial plants at the Gray Herbarium were collected in the Mediterranean area. None came from northern Europe. This would tend to indicate that they might not be able to withstand our winters; however, it is certainly worth trying to raise them as annuals, in which case they might succeed in this part of the country.

Summary

Oregano has in recent years become one of the more important herbs used in America. The botanical identity of the plants sold as oregano in the United States has been in doubt. About one-half of the amount used in this country at the present time is imported from Mexico. The rest of our supply comes mainly from several Mediterranean countries. Mexican oregano consists of the dried leaves and flowers of species of the genus *Lippia,* usually *L. graveolens.* European material is obtained from several species of *Origanum.* Many other species in different genera are called " oregano " in other parts of the world.

The term " oregano " should not be used to refer only to a single plant species but rather to a number of species, all having in common a particular herb flavor. Any herbaceous plant used as a condiment may be called " oregano " if its flavor is like that of other oregano species. Lippias and other sources of oregano can be grown in the warmer areas of the United States. The most suitable plants for the North would probably be species of the genus *Origanum.*

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Utilization Abstract

Flower Oil Industry of Southern Italy. Until about 25 years ago southern Italy (Sicily and adjacent Calabria on the mainland) had almost a world monopoly in the production of citrus oils, and at that time production of essential oils in that part of the world was almost confined to the oils of lemon, sweet and bitter orange, mandarin and bergamot. Since then Italy has gradually lost this monopoly to California and Florida, where these oils have become commercially valuable by-products in the large-scale canning of citrus juices. As a result, Italian oil producers have turned to jasmine flower oil, the total yearly production of which now approaches that of the Grasse region in southern France.

Next to oil of jasmine in importance in the Italian essential oil industry today is oil of neroli bigarade, distilled from the blossoms of the sour orange. "Potential production in Sicily and Calabria amounts to about 350 kilograms per year, but actually only from 100 to 150 kilograms are obtained. The reason is simply that growers are loath to pick the flowers. If left on the trees the latter will develop into fruit and there is a good market for brined bitter orange peel, a popular item in England. The French neroli bigarade oil is of better quality (and substantially higher priced) because in the Grasse-Golfe Juan region the blossoms are picked much more carefully than in Sicily and Calabria. Moreover, there are practically no sweet orange trees in southern France; hence any admixture of sweet orange flowers to those of the bitter orange tree is quite impossible. The same cannot be said of Sicily and Calabria".

"As regards other crops, southern Italy is now experimenting with rose, acacia and geranium. As yet, only small quantities have been produced, but there is hope that the efforts of the Stazione Sperimentale in Reggio Calabria will be as successful as they have been with jasmine". (Ernest Guenther, *Am. Perf. & Ess. Oil Rev. 62(3): 185. 1953*).

Tree-Rings and History in the Western United States

The annual rings in suitable living trees have provided significant, centuries-long histories of past rainfall, temperature and river flow for many regions and have served to precisely date several hundred Southwestern ruins by overlap-matching with ancient timbers. Some of the stunted trees in very adverse environments were found to have the most sensitive chronologies and to attain ages twice or more the usual maxima on optimum sites. Tree-ring data for the western United States show that in pre-Columbian times the accumulated excess or deficit in rainfall occasionally greatly exceeded that recorded by gages during the past decades.

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Introduction [1]

The common opinion that the rings so obvious on cross-sections of most trees may be counted to give the age of the tree, and that the succession of wide and narrow rings may be interpreted as reflecting the history of favorable and unfavorable growth-years, is indeed old—surely, the statement by Leonardo da Vinci near A.D. 1500 to this effect is the earliest only because far earlier ones were not recorded or have been lost, perhaps in the disappearance of the Alexandrian Library!

Despite this ancient recognition of tree-rings as an historical index, modern scientific research on ring-growth at first quite properly emphasized botanical and ecological aspects. By the end of the nineteenth century a truly vast amount of work had been done on the nature of such growth layers and their complex relationships to climatic and other factors.

[1] Literature citations have been almost completely omitted from this article; see research reports in the Tree-Ring Bulletin, 1934–, and an outline bibliography in the Compendium of Meteorology, Amer. Meteorol. Soc., 1951, p. 1029.

In recent decades, however, many investigators in this country and abroad have sampled various forest stands and have measured several millions of annual rings in an effort to develop long chronologies which might represent, to some extent, histories of past rainfall, temperature, river flow and other climatic variables. The stimulus for this activity arose, in good part, in an astronomical objective! Quite independently, it occurred to a Dutch astronomer, later renowned for his contributions on stellar statistics, and to an American astronomer, studying variations such as those of the markings on Mars, that the rings of trees might directly or indirectly record year-by-year changes in the sun.

Julius C. Kapteyn, about 1880, examined oak sections from western Germany and Holland and derived a 240-year ring chronology. The later decades of this history corresponded well with rainfall data, and a strong, but quite unexplainable, cyclic variation of 12.4 years was present throughout. Fortunately for astronomy, Kapteyn evidently felt this work to be strictly extra-curricular, for he carried it no further. But his single paper on the subject, a published lecture

in Pasadena in 1908, is a delight to read for its simple presentation of essentials and its humility.

In contrast to this somewhat abortive effort, the program of research initiated by A. E. Douglass at Flagstaff, Arizona, in 1904, has been carried on for almost half a century at the University of Arizona, at Tucson, and has led to important developments in quite unexpected directions. The most spectacular development was a method which made it possible to precisely date many ruins and thus provide a time-scale for the pre-Spanish cultures of the Southwest. This method is based on detailed matching or cross-dating of the patterns in tree-rings—an application of the operation of forecast-and-verification, which is such an integral part of the scientific method. It proved to have far-reaching implications in climatic studies as well, for it was the essential key to the development of highly significant tree-ring histories of rainfall and other climatic variables.

We thus see that modern techniques in dendrochronology find their principal application in two fields of research: (*a*) dendro-climatology, that is, historical climatology based on fluctuations in ring-growth, and (*b*) dendro-archeology, the dating of prehistoric structures and activities by the precise dating of ancient wood. Before we consider the contributions in these two fields, however, it may be illuminating to directly examine some tree-rings of the sensitive type useful in dendrochronology.

The photographed outer rings in radial increment cores from the lower stem of selected living Douglas-fir trees are shown in Fig. 1. These represent the ring chronologies in recent decades in three localities of the Colorado River basin—the isolated and arid Nine Mile Canyon of northeastern Utah, the archaeologically rich Mesa Verde of southwestern Colorado, and the Tucson area of southern Arizona—a range of over 500 miles north-south.

In the outermost ring at the extreme right in the upper photograph of Fig. 1, the band of light-colored earlywood must have been laid down largely during June and early July, as is characteristic of mountain conifers near the lower forest border throughout the western United States. The growth of dark latewood cells, which complete the year's ring, is commonly found to be essentially over by the end of July. Since the tree was sampled June 6, 1950, the ring for 1949 is complete; that for 1950 had not yet started on this core. Similarly the Tucson core (lower), taken May 22, 1951, ends with the 1950 ring. The Mesa Verde core (center), on the other hand, was cut later in the season, October 2, 1951, and therefore has the 1951 ring complete.

That the same general pattern of thick and thin rings may be found in selected trees over a fairly large area is also illustrated in the photographs. These ring series represent not only the succession of good and poor growth years, but also, as will be pointed out below, a significant record of excessive rainfall or drought for the entire year preceding the end of the growth season. Anticipating these conclusions, we note some interesting details of climatic history in Fig. 1. Although the ring growth in individual trees must, even at best, be subject, to a considerable extent, to purely local or random influences, certain outstanding climatic events in the Southwest are well shown. The unusually snowy "haylift" winter of 1948–49 in northern Utah-Nevada resulted in the very thick 1949 ring in the Nine Mile tree (upper); the rainfall excess was less pronounced to the south, as the Tucson core suggests (lower). The widespread drought of the "dustbowl" year 1934 is represented by a very narrow ring in all three areas. The general deficiency in

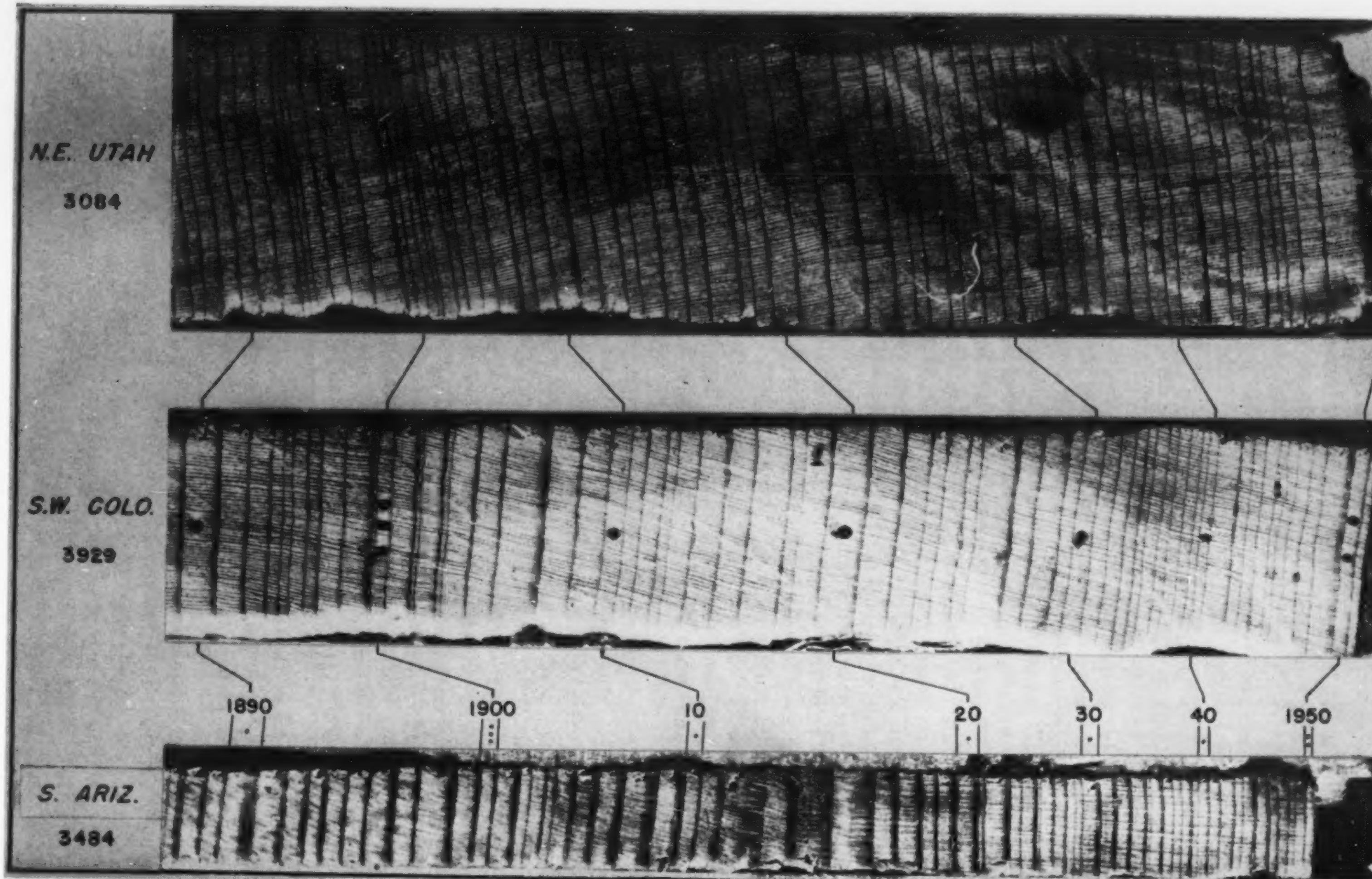


Fig. 1. Cross-sections, obtained as increment cores with a borer, of Douglas-fir trees in three localities of the Colorado River basin. The center of the trees was at the left of the photos, the bark at right edge. Each annual ring consists of a wider, light-colored, less dense portion of wood, formed in late spring and summer, and a much narrower, denser portion, formed later and represented in the photos by the perpendicular dark line to the right of each of the lighter-colored bands. The circular dark spots are decade date-marks.

The ring-widths in these particular dry-site and sensitive Douglas-firs are closely proportional to the local rainfall. Most of the specially narrow or wide rings in any of these series may be recognized in the others, in accord with the generally widespread nature of drought or wetness in the Colorado River basin. Magnification: upper, ×10; middle, ×8.2; lower, ×3.5.

growth in the outer two decades or so in the more northerly areas of the Colorado River basin, and since 1920 in the Gila River tributary basin, represents a rainfall fluctuation of major economic importance.

Further, 1904 is generally represented by a narrower ring than 1902 in southern Arizona, in correct relation to the rainfall; but in northeastern Utah the trees, like the rain-gage records, show the July 1901–June 1902 interval to be the drier year. The flow of the Colorado River at the Grand Canyon is largely subject to the rainfall in northern Colorado and Utah; the water-year 1902 (ending September 30) had the minimum flow of record preceding 1934.

On the other hand, the low rainfall of the 1898–99 season and the correspondingly narrow ring which is observed over most of the Colorado River basin are in great contrast to the very heavy mainstream runoff for 1899, the result of an unusual concentration of heavy snows in the headwaters area. The importance of a sufficiently dense and widespread sampling network is thus obvious.

Dendro-Archaeology

The method of overlapping patterns by means of which prehistoric beams may be dated is illustrated in highly idealized form in Fig. 2. It is evident that matching the outer rings of an old beam with the inner rings in a living tree serves two purposes, namely, to date the old beam and to extend into earlier times the potential climatic chronology in the living tree.

Those acquainted with the great range of variability, which seems to be one of the universal properties of biologic elements, will recognize that such simple growth and perfect synchroneity from tree to tree as shown in the figure is quite unlikely to be found, even in trees of one species and within a small locality.

In many species and individual trees, the rings are so complex and variable that cross-referencing with other rings is not possible. Indeed, the botanist is familiar with so many reasons for such ring irregularity—specific characteristics, environmental influences, accidental events, and so on—that close parallelism in ring fluctuations among different trees might well seem the rare exception. It was fortunate for the pioneer work in dendro-archaeology that it was applied in the Southwest, where species, climate, site and wood collecting by the ancients all so happily favored the research. It should not be supposed, however, from the foregoing that such cross-dating is a characteristic only of certain Southwestern trees. This property has now been found present in many other regions, though nowhere in such good form in so many trees.

The tendency of the ring-widths in dominant conifers of the Southwest—*Pseudotsuga menziesii, Pinus ponderosa, P. edulis*—to show approximately the same patterns over a large area made it significant to take broad-scale averages of many trees and thus derive a so-called master chronology. In this way local peculiarities in growth were minimized and the master chronology served as a general standard, against which beams from widely separated localities could be dated.

The development from living trees and relatively recent house beams of a master chronology which extended back into the time of the prehistoric Pueblos was not accomplished at once—the dating of the Cliff Dweller ruins, announced by Douglass in the National Geographic Magazine in December, 1929, was preceded by over a decade of collection and analysis of archaeological wood. A number of floating chronologies were developed, built up of ancient beams which cross-dated with each other but which could not be joined to the dated rings of the living-tree master record; a gap of un-

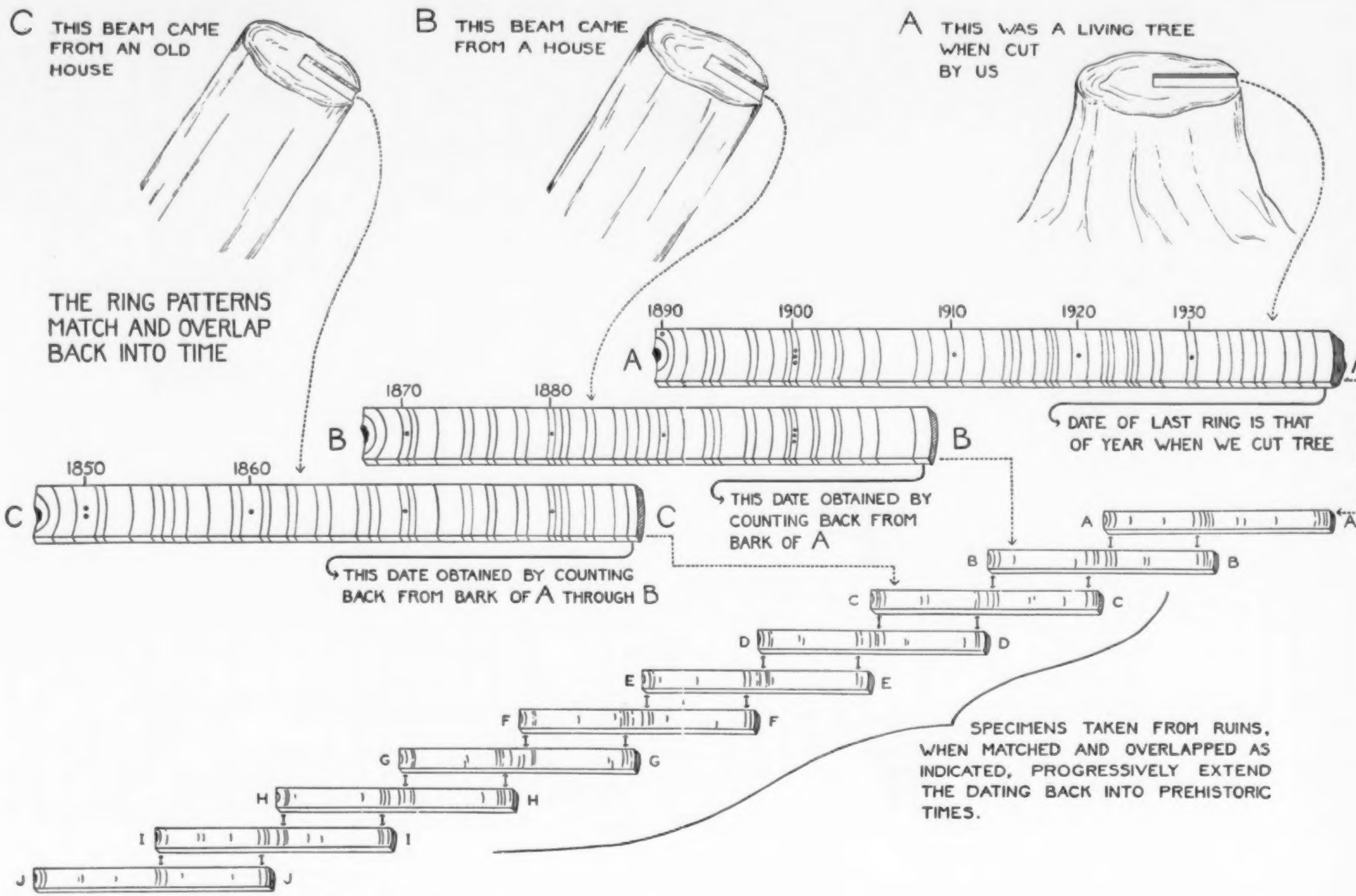


FIG. 2. The matching of ring spectra may not only show when a beam from an archaeological site was felled but may also lead to a long backward extension of the ring history of climate in living trees. (From Stallings: Dating Prehistoric Ruins)

known length had to be bridged. At last beams were obtained which did overlap the inner part of the master chronology, and immediately dates could be assigned to several scores of ruins in the Southwest. The most magnificent of these, the apartment houses of the " cliff dwellers ", as at Mesa Verde National Park, were among the most recent, principally in the 1200's A.D.

The 1929 " Crossing of the Gap " initiated a period of intense activity in dendro-archaeology. Earlier and still earlier ruins were dated in the Central Pueblo area; independent master chronologies were developed for the Rio Grande by W. S. Stallings and for northeastern Utah by Schulman; and now the dates of several hundred ruins and a chronology for the Southwest reaching back 2,000 years have been established. By similar methods dates have been obtained by various investigators for less ancient works of man in Norway, Sweden, Germany, and particularly, by J. L. Giddings in Alaska.

As an example, we may note a recent application (1952) of this method, namely, the extension of the Puebloan chronology into B.C. times. The ring sequence in a very sensitive and consistent ancient beam of Douglas-fir from Mummy Cave, northeastern Arizona, was definitively dated by comparison with master chronologies and with individual specimens long dated and available for several localities in that area. The inner part of a portion of the Mummy Cave beam is illustrated in Fig. 3.

This extension of the known chronology then made possible the dating of a number of short charcoal fragments from an early archaeological site near Durango, Colorado. Among these fragments was one with attached bark, the outer ring of A.D. 46 providing the earliest precise culture date presently available for the Southwest. Some of the evidence on which this extension of the Southwestern chronology is based is shown in Fig. 4.

It will be evident from the foregoing that, in general, the successful application of tree-ring analysis to archaeological dating requires two principal favoring factors which are, unfortunately, by no means widely found:

1. One or more living species must exist in which, on at least some type of site, the annual rings are sharply defined, show fairly high year-to-year changes in ring-width, vary in essentially parallel fashion along different radii and from tree to tree, and provide centuries-long sequences.

2. Available archaeological beams must be of the datable species and from the datable types of sites, in general must overlap the time range of the master chronology for at least 50 years, and must have sufficiently high ring sensitivity to provide unqualified dating. (Since the ring chronologies in any region tend to be much alike over broad areas, the preceding restriction is not so severe as it might otherwise be.)

For specially favored localities of the Pueblo area, ring chronologies in some species are so simple and consistent that reliable archaeological beam-dating, given a sufficiently long master chronology, is an absurdly simple matter. But this is far from true in general. Definitive beam-dating requires, first, a professionally secure solution of all problems, such as those presented by false annual rings, and, second, an identification which is not merely probable but absolute with a selected segment of the master chronology.

Absolute identification is possible by the forecast-and-verification method. Given a tentative matching of test specimen and master chronology by some ring characters, corresponding additional characters (locally-absent rings, check-segments of the ring sequences outside

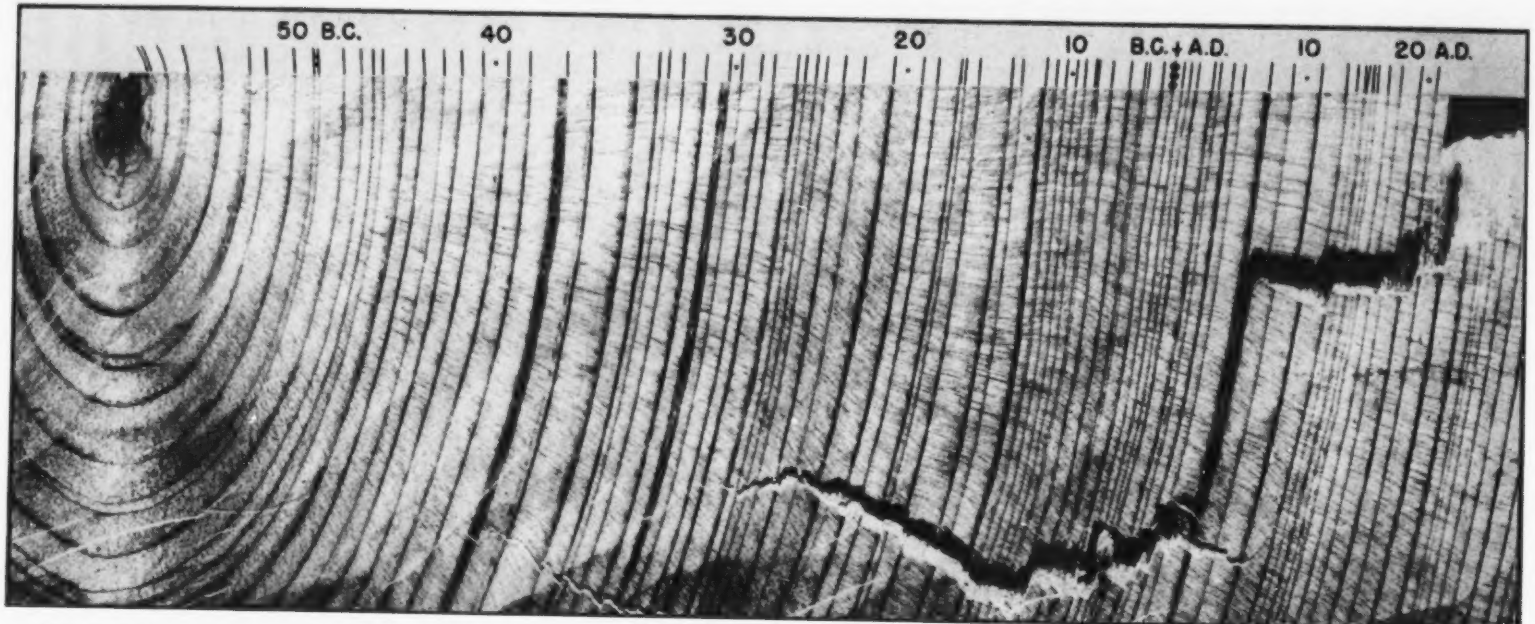


FIG. 3. The first information about Southwestern rainfall in specific years during B.C. times was given by these annual rings in a recently dated Douglas-fir beam, GP-2997, from Mummy Cave, in the Navajo Reservation, Arizona. Magnification ×3.4.

the test-dated interval, etc.) are sought; with a sufficient number of verifications the probability of chance correlation becomes vanishingly small. Since such verification depends on fairly close congruence of both ring sequences, such parallelism should appear in the compared measured growth curves and in the correlation coefficients, especially of the check or forecast intervals.

The unqualified archaeological dating to the year which tree-ring analysis makes possible under favoring circumstances is, from a world-wide point of view, of highly limited application. Even in the Southwest, ruins yielding only juniper or hardwood beams cannot be directly dated; in many other regions the absence of favorable species makes the construction of sufficiently long master chronologies extremely difficult or quite impossible. This deficiency has been met in a most unexpected way.

In the last few years a new method has been devised, by W. F. Libby of the Institute for Nuclear Studies of the University of Chicago, for the dating of wood and other materials by the measurement of the amount of decay in the radioactive isotope of carbon, C^{14}, which these materials contain. This very elegant and powerful technique, now in process of active development, is applicable to a wide range of organic and other material and appears able to provide dates from about 1,000 to some 30,000 years in the past with a probable error that is satisfyingly small. By supplying an absolute time-scale for regions where the construction of a master tree-ring chronology anchored in the present is impossible, C^{14} dating greatly increases the value of possible relative tree-ring dates in some of these regions.

Dendro-Climatology

Principles. Evaluation of all the influences responsible for the observed absolute growth of trees is obviously a far more complex matter than that of setting up a centuries-long tree-ring index of climate. Nevertheless, even with the latter limited objective, the numerous pitfalls in analysis and interpretation of ring-growth permit no simple generalizations of the results of work in dendroclimatology. It will perhaps be sufficient to sketch certain broad outlines as follows:

1. A most fundamental property of all phases of ring-growth is variability; no conclusions based on one species or stand are necessarily generally applicable.

2. Coniferous species are usually preferable to hardwoods as sources of climatic chronologies because of longevity and ease of sampling and analysis [2]; however, their dominance in the most "sensitive" belts thus far studied may unduly determine this view.

3. As a single meteorological element becomes severely limiting in tree growth —e.g., temperature near the arctic tree line or moisture near the lower forest border on mountain slopes of semi-arid regions—the door seems to close to the entry of numerous random factors which in part control the fluctuations in radial tree growth in mesophytic areas.

4. A powerful tool for the solution of uncertainties and elimination of errors in ring identity is provided by the cross-dating technique already emphasized, in which the sequences of widths are matched ring by ring; only when a general tendency exists for parallelism

[2] Sampling is done principally with the Swedish increment borer. This permits a widespread survey without damage to the trees. The cores, about four mm. in diameter and up to 15 inches long, may be quickly surfaced with a razor blade by use of a sliding cut with the grain and at a low angle to it. On the resultant undamaged cellular surfaces, rings two to three cells thick, that is, less than 0.10 mm. wide, may be readily seen with a low-power hand lens and proper lighting, and several cores may be examined simultaneously.

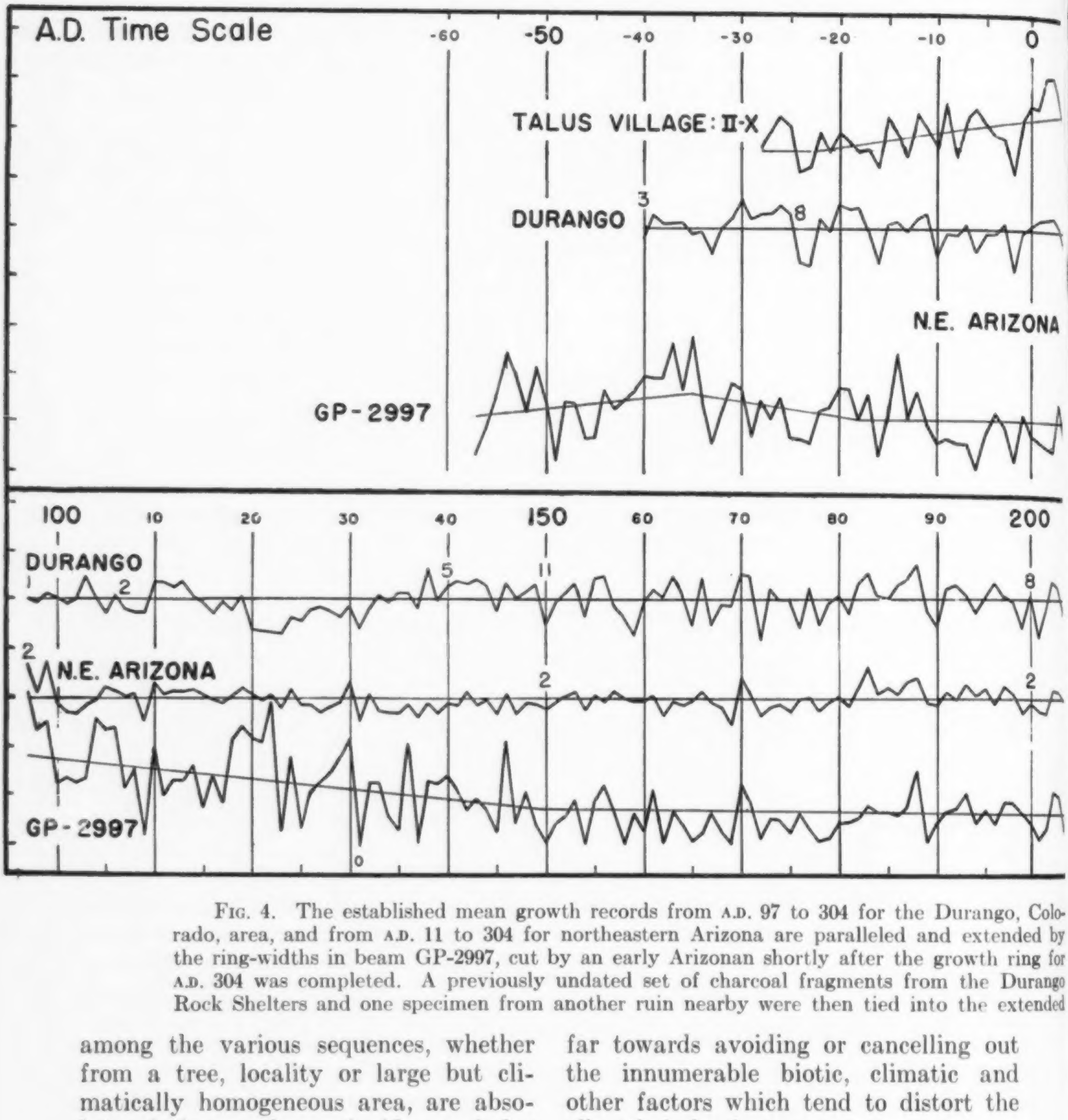
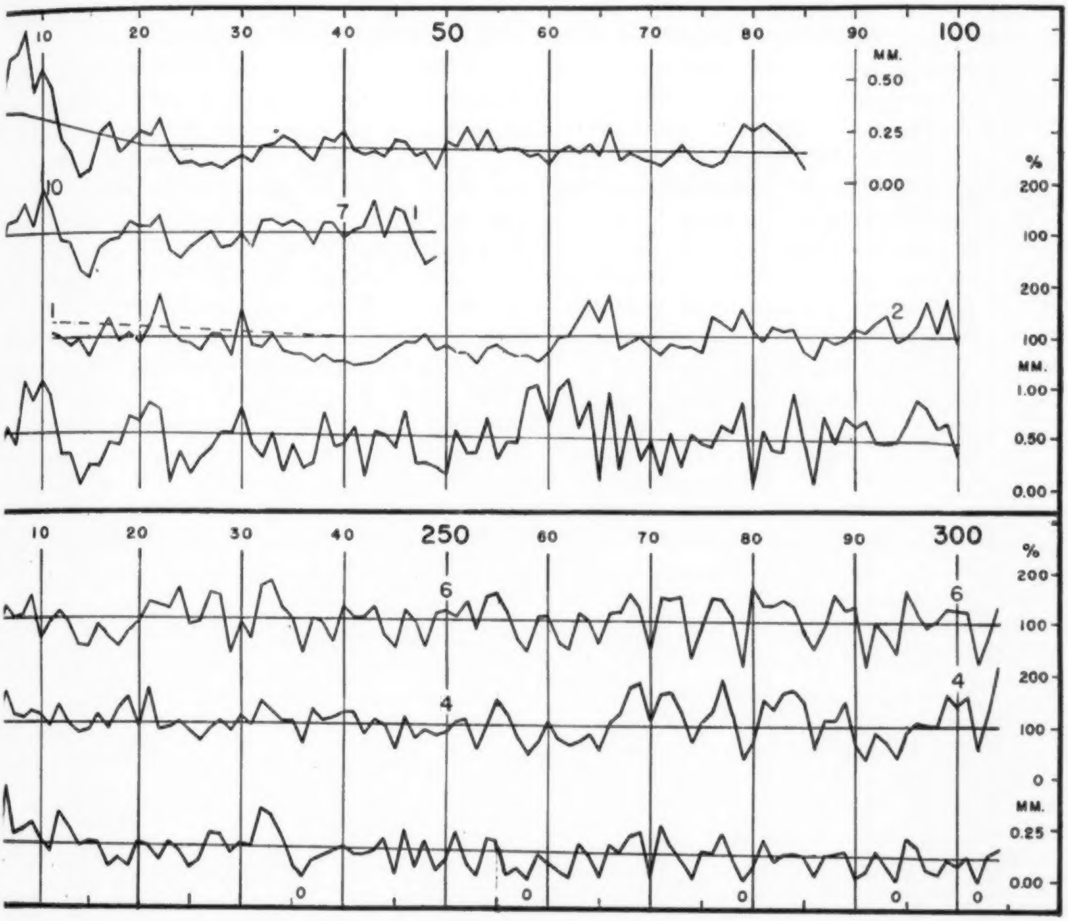


FIG. 4. The established mean growth records from A.D. 97 to 304 for the Durango, Colorado, area, and from A.D. 11 to 304 for northeastern Arizona are paralleled and extended by the ring-widths in beam GP-2997, cut by an early Arizonan shortly after the growth ring for A.D. 304 was completed. A previously undated set of charcoal fragments from the Durango Rock Shelters and one specimen from another ruin nearby were then tied into the extended

among the various sequences, whether from a tree, locality or large but climatically homogeneous area, are absolute dating and a significant index possible.

5. The dendro-climatic history of a region, if derivable at all, is an approximation which it is usually possible to replace with a better one. By repeated sampling of trees, selected according to improved field criteria, and by the construction of indices having a wider statistical base, it may be possible to go far towards avoiding or cancelling out the innumerable biotic, climatic and other factors which tend to distort the climatic index in trees.

Over-Age Conifers and Chronology. The spectacular achievement in archaeological application of a botanical variable was not the only unexpected offshoot of dendrochronologic research. An intensive field search by the writer during the past 14 years for suitable tree sources of climatic data has brought to light a remarkable category of long-lived



record. Trend lines are superposed on the growth curves, and the number of component trees are noted along the group curves. A zero year has been introduced for graphical continuity, so that earlier dates are displaced one year with respect to the B.C. scale; thus, −49 A.D. corresponds to the narrow ring 50 B.C. in Fig. 3. (From Tree-Ring Bulletin)

growth-stunted trees of high index value. These not only provide a unique kind of tree-gage record of past rainfall but exhibit very suggestive properties of growth under extreme adversity.

Rain-recording trees of great longevity are of specially high value in dendroclimatic studies, not only because they provide long histories but also because they make possible a greatly improved estimate, as compared with young trees, of the absolute values of past rainfall. Since the actual amount of annual radial growth of the stem is a function of the tree's age, species, environment and other factors, the growth must be expressed in departures from the mean trend, preferably as percentages, in order to derive climatic indices. Obviously the position of the trend line fitted to the data may be raised or lowered if the series is extended; this so-called end effect is usually of little importance in the outer part of the growth curve of a mature tree, where the mean growth rate has usually approached a nearly con-

stant value, but may be critical in the early part of the record, where the rate is usually changing fairly rapidly. Since the age-trend in over-age chronology trees is especially shallow except in the earliest decades of growth, these trees can provide indices which represent a good approximation to absolute values. On the other hand, it is evident that any small secular trend in climate would be completely hidden in the fitted trend line and thus would not be determinable even in these trees.

A typical site on which such trees may be found is illustrated in Fig. 5. For many miles bordering the upper Colorado River, as in this area just west of Eagle, Colorado, stunted Douglas-firs and pinyon pines (*P. edulis* Engelm.) dot the steep slopes and are readily accessible from the highway. Standing dead poles are common. That this site happens to be a gypsum formation may have no great significance, since trees of comparable age, sensitivity and slow growth have been found on sandstone or limestone slopes nearby; however, the number of extremely old Douglas-firs per unit area is greater here than at any other site in the Rockies thus far sampled by the writer. A closer view of one of the trees in Fig. 5 is shown in 6*a*. The dead snag above a small cluster of live limbs is characteristic of many overage Douglas-firs.

Another excellent source for drought chronology trees is the Bryce Canyon National Park area. The stunted Douglas-fir in Fig. 6*b*, photographed in its dying years, has for some seven centuries been overlooking what is now called Bryce Point. In Fig. 7 the roots of this tree, exposed for hundreds of years, show a two-foot loss of soil during the tree's life. The increment borer, which makes available 15-inch cores, provides a scale.

On the basis of several hundred sampled trees which were suitable for chronology studies and which exceeded the commonly assumed maximum age of about 500 years for Rocky Mountain conifers, certain characteristics of these drought-site trees emerge as probably very general in nature: (*a*) the absolute maximum ages of Douglas-fir, ponderosa-pine and piñon-pine in the Rocky Mountains are of the order of 1,000 years, and for *P. flexilis* (limber pine) in excess of 1,650 years [3]; (*b*) in addition to the observed tendency for maximum longevity on the most adverse sites, there seems to be a systematic though probably only indirect relation to latitude in the age limits of various stands of a given species; (*c*) the median ring-width in the lower stem is about 0.30 mm.[4]; (*d*) this growth rate is often approached by early maturity—two or three centuries—after which the mean growth-rate decreases very slowly; (*e*) the absolute minimum in total mean radial growth of the lower stem for an entire century is about eight mm.; (*f*) the number of sapwood rings in overage Douglas-fir does not seem to be significantly related to either the number of heartwood rings or the thickness of heartwood (for relatively young trees a systematic relation has been found by Stallings when groups of five or more

[3] The extraordinary longevity in certain stands of the high altitude pines *P. flexilis* and *P. aristata*, observed in very recent field sampling by the writer, is being reported in detail elsewhere; the chronologies in the oldest known *Juniperus scopulorum* (the Jardine Juniper of Logan Canyon, Utah, about 1,500 years) and in *J. osteosperma* or *utahensis* (about 1,650 years) are of doubtful climatic significance.

[4] It may be noted that Douglas-fir on locally moist sites in this generally dry region may attain growth rates comparable to those in wet-climate regions: the "Hitchcock Douglas-fir", over 125 feet in height and 7 feet base diameter, a recent windfall in the Santa Catalina Mountains near Tucson, Arizona, had an average ring-width of 2.53 mm. for the 281 years of growth at the 12-foot level (5.06 mm. for the inner 50 years).

trees are averaged); (*g*) false rings are almost completely absent in these overage trees of all species except the scopulorum juniper, and there is a marked tendency to decreased incidence of locally absent rings in higher latitudes.

The asymmetric age distribution is most clearly noted in drought-type Douglas-fir, which has been sampled on many sites throughout its range of some 30° of latitude in the inland western cordillera from central Mexico to Jasper National Park, in Alberta. In a belt roughly defined by latitudes 39° and 40° in the Colorado River basin of eastern Utah and western Colorado literally thousands of trees may be found from 700 to 900 years old. Curiously, Douglas-fir east of the Continental Divide in these latitudes and also in the Great Basin ranges to the west of the Colorado River basin shows much lower maximum ages. Although the distribution of such trees is, as already noted, highly dependent on local site conditions and therefore very spotty, there is a decided tendency to generally decreased maximum ages both northward and southward. Douglas-firs in the 600-year age class may be found in considerable numbers on careful search in southern Utah and southwestern Colorado, but are, in contrast, quite rare in the forests of northern Arizona and New Mexico, and in the writer's knowledge are unreported in the southern areas of these states or in Mexico, where the average maximum age seems to be about 350 years. Maximum ages are generally less than 600 years northward from the 39°–40° belt to the Canadian border, are less than 500 years in southern British Columbia and at Banff, and may be no more than about 400 years near the northern limits for the species in central British Columbia and at Jasper Park.

FIG. 5. Methuselah Douglas-firs, growing very slowly, are characteristic on these arid slopes near Eagle, Colorado.

Much less complete sampling of species other than Douglas-fir does not allow more than a suggestion of the age distribution pattern. One limber pine maximum seems to occur near 44° in eastern Idaho, the pinyon pine in the 39°–40° belt, like the Douglas-fir maximum, and the ponderosa pine in the 37°–38° belt in southern Utah; all species seem to show a marked decline in maximum ages southward and to a lesser degree northward of the respective belts of maxima.

FIG. 6*a*. One of the 700-year trees in Fig. 5.

FIG. 6*b*. On the upper slopes and ridge-tops in Bryce Canyon National Park many centuries-old trees like this one may be found, adding only an inch or so of radius per century yet providing a good year-by-year ring index of changes in rainfall.

Climatic Histories. In the Scandinavian arctic, ring indices up to five centuries in length and with correlation coefficients of the order of +0.7 against observed growing-season temperature are obtainable, particularly at or near the northern tree limit; in the drier areas of the western United States and southwestern Canada, ring indices up to 1,000 years in length and with coefficients of +0.7 to +0.8 against total yearly rainfall ending in June or July are obtainable, particularly at the lower, or dry, forest margin. The significance of the ring record in upper timberline trees of mid-latitudes is not yet entirely clear. For more stress-free areas, such as the eastern United States and central Europe, variant conclusions have been reported as to the climatic significance of ring-growth—e.g., no relation, fair rela-

tion to the annual number of rainy days, pronounced effects in years of physiological drought, and moderate relation to rainfall of certain months. However, C. J. Lyons and others have shown that in such mesophytic areas the basis for significant ring histories does exist in the fair degree of crossdating which may be found in selected species and trees.

When properly analyzed, the sequences of ring-widths in over-age drought conifers may provide long and highly significant extensions into the past of the gage records of rainfall and runoff.

It must be emphasized, however, that the correlation observed for recent decades between growth and rainfall may be applied only with diminishing assurance to successively earlier centuries of growth index. It has already been noted that the effect of hypothetical secular trends in climate, such as a steady decrease in mean rainfall by as much as 5 percent during the life of a tree many centuries old, cannot at present be separated from the tree's decreased radial growth as a function of age. Other centuries-long, non-climatic effects on growth rate, such as might conceivably result from radical long-term fluctuations in the activity of the soil microorganisms, must remain as a source of uncertainty which only the most widespread sampling can in part reduce. These considerations do not, of course, apply to fluctuations from decade to decade.

Three critical regional indices for the western United States, based on the ring growth of dry-site conifers of the type just discussed, are compared with appropriate water-year flow data in Fig. 8. The strong parallelism to be noted in this figure suggests that variations from year to year in the pattern of climate—distribution and intensity of storms, anomalous temperatures, the varying ratio in different years of runoff to rainfall, etc.,—introduce only a relatively small error in such regional indices. It is highly probable that local biotic and other factors are to a substantial degree cancelled out in these large-scale means.

FIG. 7. A 4-mm. core from bark to pith may be readily obtained with the Swedish increment borer. Even the oldest resinous conifers quickly seal off the slight wound. Bit length above handle, 15¾ inches.

Pronounced differences in some years in the march of the compared variables will undoubtedly be corrected somewhat with more representative tree indices which await development; minor errors in the river-gage data no doubt also exist and may be found and corrected. For example, re-examination of the early gage measurements at Fort Benton, Montana, recently led to somewhat reduced annual totals for the flow of the Missouri River at this station from 1891 to 1918, as shown in the figure. Despite such improvements in the data, however, it cannot be hoped that the observed correlation between river flow and the best regional tree indices will ever substantially exceed about +0.85, the pres-

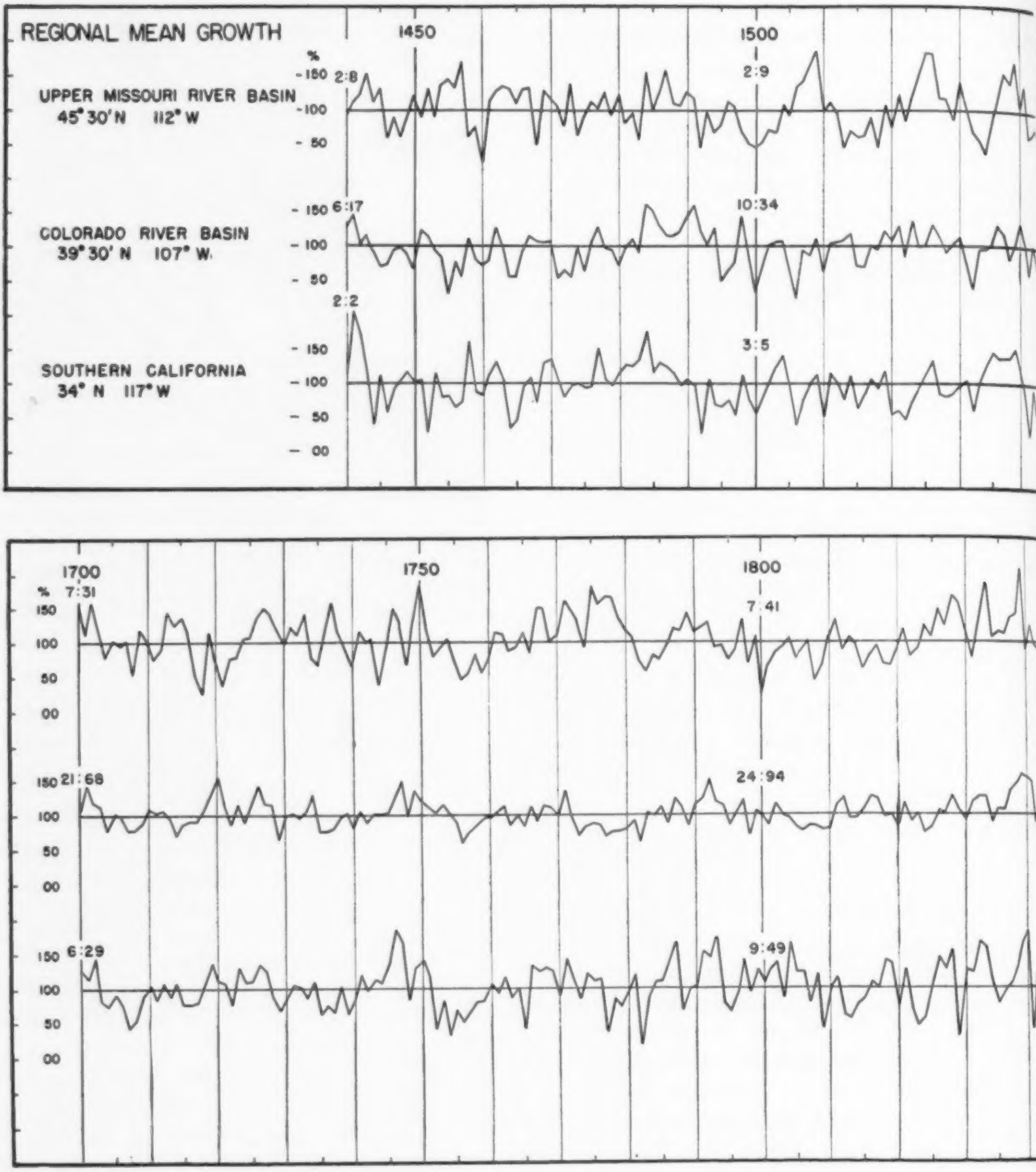
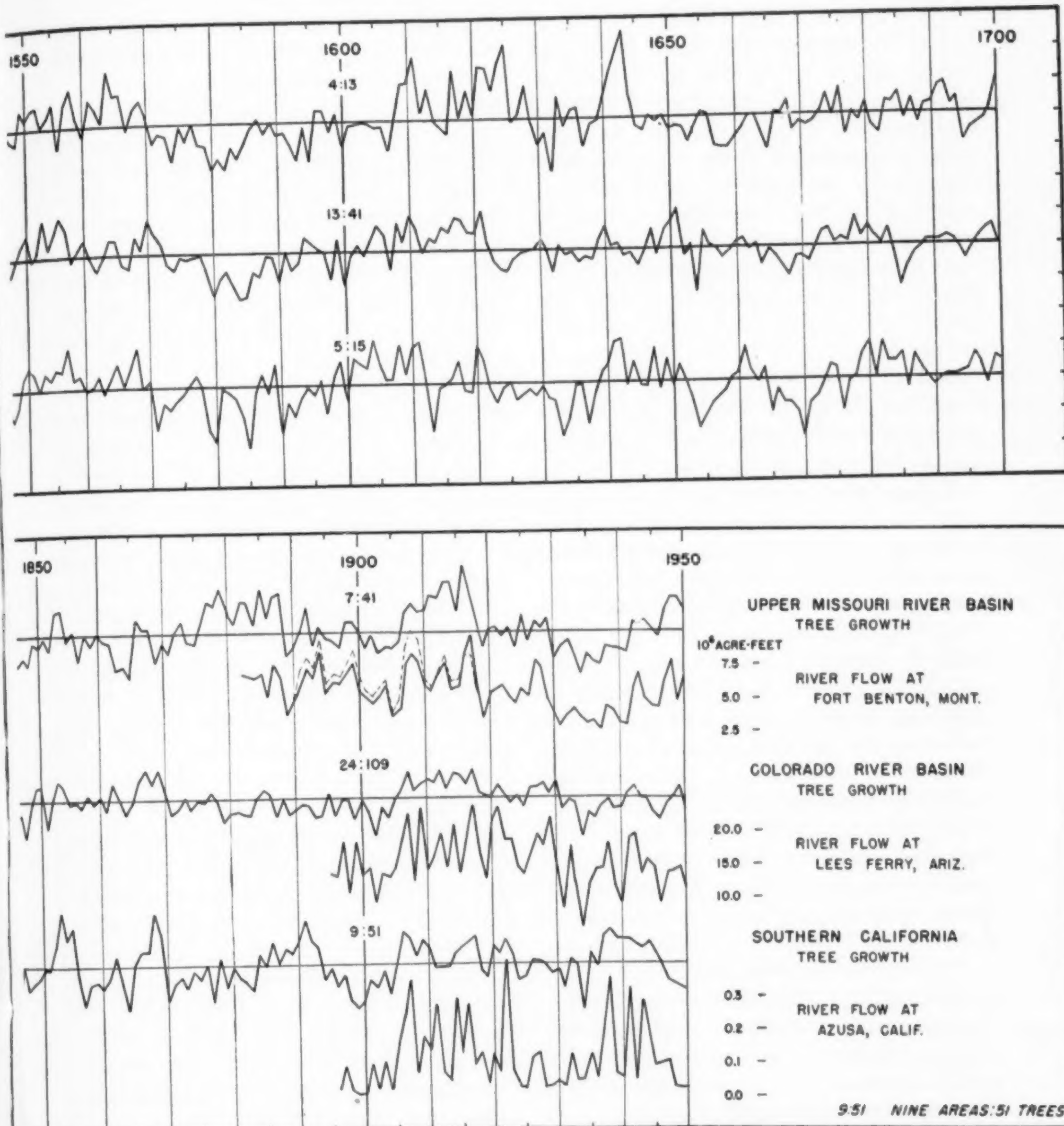


FIG. 8. Regional growth indices based on drought-sensitive trees of the western United States parallel the major and most of the minor fluctuations in measured river flow at appro-

ently observed value for some of the comparisons.

Certain features of the probable past rainfall in the western United States suggested by Fig. 8 may be specially noted. A strong though by no means perfect parallelism is evident between the Colorado River basin and southern California. The final 25 or 30 years of the 1500's in these regions seem to have been characterized in general by deficient growth, rainfall and river flow of severity substantially greater than that in the recorded "dry spells" near



priate stations and thus provide a view of the approximate march of this variable in earlier centuries.

1900 and 1934; data based on the oldest trees appear to show, in fact, that this was the worst drought since the century-long dryness of the 1200's. The pronounced deficiency of the late 1500's seems to have affected the Missouri River basin also. The occurrence of two extremely deficient years in succession, however, is apparently quite rare, except during the major general minima. The bearing of inferences of this nature on water and power reserves, such as those at Hoover Dam on the Colorado, is perhaps obvious.

The minimum near 1900 in water supply in the Southwest, evident in the figure, is less severe in the upper Missouri River basin and, in fact, is replaced still farther north by what appears to be the greatest maximum in three centuries, at latitude 51° in Banff National Park.

It is of no little interest to find, in the over-age conifers, a strong suggestion that a century of great drought in the Southwest was followed during the 1300's by a century of seldom interrupted rainy years. This very wet interval was perhaps the greatest in two thousand years in this region, as the supplementary evidence in the archaeological chronologies suggests.

A great deal of attention has been devoted to the attractive hypothesis that tree-ring series contain a history of solar or other extra-terrestrial variations, especially cyclic ones. Some instances of direct parallelism which have been noted between sunspot variation and the ring growth of certain trees are often cited and may indeed not be entirely due to chance. In general, however, extra-terrestrial variations, if they are recorded by trees, must be in very complex form and are largely obscured by what seem to be random cyclic variations, for no aid towards the solution of the problem of long-range climatic forecasting is as yet established in growth cycles. Nevertheless, the very great importance of the problem and the strong evidence that real, if hidden, non-terrestrial effects are, in fact, present in such growth cycles, would seem to justify continued scientific inquiry.

Geographic Distribution of Drought Conifers. Do over-age conifers providing significant rainfall chronologies exist on other continents? It now seems quite certain that they do.

Along the foothills of the Patagonian Andes of Argentina, between latitudes 38° S. and about 43° S., dry sites comparable to the semi-arid Rocky Mountain margins were sampled in early 1950 by the writer. In two coniferous species, *Araucaria imbricata* Prav. and *Libocedrus chilensis* Endl., the ring records showed the characters of sensitivity and crossdating which are essential for the derivation of climatic chronologies. Since these conifers are developed only in scattered stands in a very thin and short belt between the line of the Andes and the plains, little area is available for development of long-lived strains. Yet the same inverse relation between mean growth-rate and age was found for the two Patagonian species as for the conifers of the Rockies. When the analysis of these collections and others in southern Chile is completed, some hundreds of years of climatic chronology for Patagonia should be available.

Xerophytic conifers, and possibly some hardwood species, exist in apparently suitable environments in a number of other regions, particularly in Asia, and will probably be found to provide significant rainfall chronologies; little exploration seems yet to have been made of the extensive Siberian forests as sources of temperature chronologies. In the light of present knowledge, however, it appears that the combination of factors which makes possible long tree-ring histories of climate is particularly favorable and widespread in western North America.

Wheat Breeding and Our Food Supply

The capacity of the United States to produce wheat has been greatly increased through research. Improved varieties and better ways of growing them have made higher acre yields possible and have reduced losses caused by many wheat pests.

L. P. REITZ [1]

Wheat (*Triticum aestivum* L.) is grown in more than 50 countries of the world and in most of the 48 States in the United States. Ground into flour, it is one of the main staples in the diet of people in America, Europe and many other areas.

The United States produces about a billion bushels of wheat each year, worth two billion dollars to the farmers and as new wealth to the country. Half of the crop is milled into flour for domestic use which is baked into five billion dollars worth of bakery products plus home-made pastries and breads of endless variety. Each of our 150 million people is provided with an average of 135 pounds of wheat flour per year. It requires about 80 million bushels of seed to resow the crop each year. Over 100 million bushels are fed to livestock, a little enters the industrial alcohol trade, and about 300 million bushels are exported annually (59).

Wheat improvement in the United States will be outlined in this article. Breeding and otherwise discovering better varieties of wheat have had far-reaching effects on our ability to produce large quantities of this important food.

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Introduction and Establishment of the Crop

Carrier (12) and Ball (5) summarized the early history of wheat-growing and improvement in this country. Wheat had to be introduced from other lands because it was not a native crop. Columbus brought it from Spain to the West Indies in 1494. Wheat from Spain was taken to Mexico in 1510, western South America and southwestern United States soon afterward, to provide a basis for club, poulard and common types rather well suited to the conditions of those regions.

Fishermen and explorers brought English, Dutch, Swedish and French varieties to different points along the north Atlantic coast and made observations on them as early as 1578, but it is doubtful that permanent culture was established by these early trials.

The Colonial period of the 17th and 18th centuries was important because of the diversity of origin of the colonists and, hence, of the kinds of wheat varieties brought to the new continent. Ball (5) stated that " it was fortunate that the United States was settled as a series of colonies, and over a long period of years . . . from several different countries of Europe. These facts insured that many different kinds of wheat were brought here with successive immigrations, thus guaranteeing the best possi-

ble foundation for making variations in adaptation apparent and allowing for crossing and variation to occur ". There resulted from this period a screening out of poorly adapted forms and a perpetuation of valuable source materials for later cultivation.

Red Lammas, the prototype of Red May, became established before the Revolution and was especially important in Virginia. Red Chaff, a white wheat, now known as Goldcoin, dates to 1798.

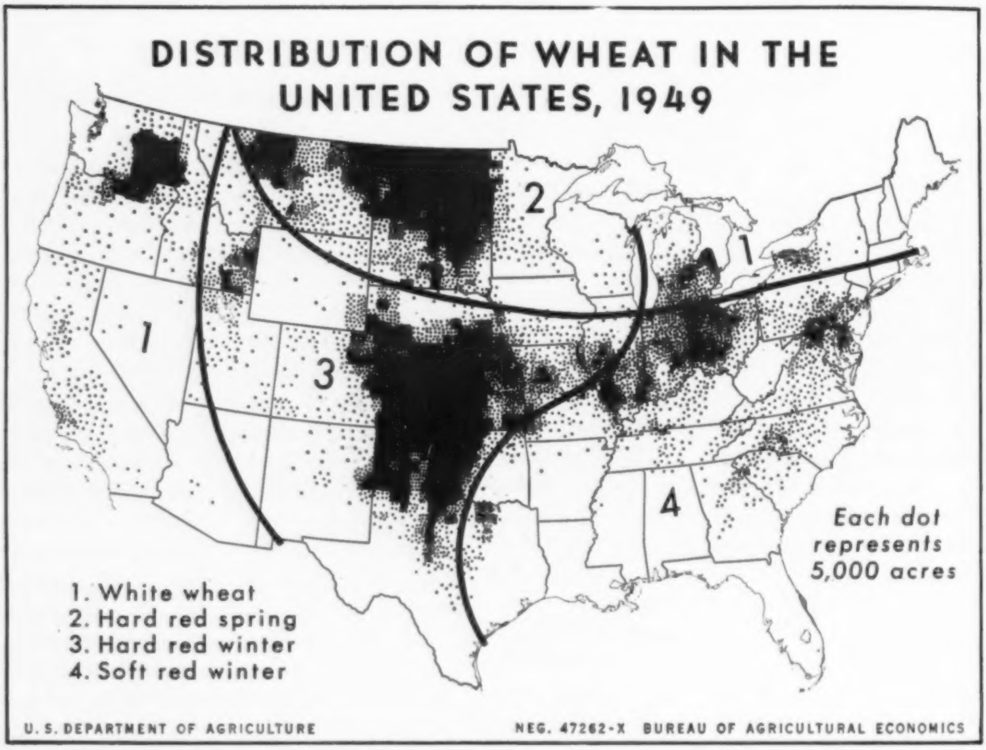

FIG. 1. General distribution of the types of wheat grown in the United States. The durum type is grown in area 2. One billion one hundred thousand bushels of grain were produced from the 76 million acres of wheat harvested in 1949.

Several other introductions were to have great influence on wheat expansion in the United States. Mediterranean, introduced from some part of the area of that name in 1819, soon was widely grown because of its good adaptation to the southern corn belt area. Purple-straw, from a source unknown, dates from about 1822 and was the basis for the wheat industry in the southeastern States. White Australian, later called Pacific Bluestem, reached California from Australia by 1850 and proved to be a high quality variety for the west. Red Fife, a hard red spring wheat, selected from a field of wheat in Canada in 1842, found its way into the spring wheat belt of the United States after 1860. The introduction from Russia of Turkey winter wheats to Kansas, Iowa and Nebraska during the period 1873 to 1900, and of the durums to North Dakota, South Dakota and Minnesota from about 1885 to 1902, complete the list of varietal types making wheat production a biologic reality in all areas of the

United States where wheat is currently important. Figure 1 outlines these major wheat-producing areas according to type of wheat grown.

Expansion to New Areas

Wheat was taken inland by the early settlers, the pioneers in the Midwest, the Far West and the Plains. Ball et al. (6) traced this movement from 1839 to 1919. Figure 2 shows the approximate wheat production centers by decades during this period, to which have been added representative years for the more recent three decades. The general westward movement of wheat across the country is shown. A decided northward swing occurred at the turn of the century when much of the hard red spring and durum wheat area was brought into production. This was followed by a surge of production of hard red winter wheat in Kansas and nearby Plains States at the time of World War I and in recent years. Simultaneous expansion in the Far West has now brought the center of wheat production to the very geographical center of the country, a point midway along the Kansas-Nebraska boundary line.

Expansion of wheat-growing in new areas seems at first to have been a simple matter of migration, but successful wheat-growing was possible only because of the special adaptation of a few varieties without which the migration would have failed. This is well illustrated by the uncertainty that prevailed about wheat as a crop for the new areas being settled. As late as 1889 the Kansas Agricultural Experiment Station published a bulletin entitled "Arguments for Wheat Raising in Kansas", reflecting the doubt which prevailed among growers. The Kansas scientists were confident, however, that wheat

FIG. 2. Centers of wheat production in the United States by 10-year intervals from 1839 (circle 1) to 1949 (circle 12).

would become an important crop. Introduction and use of Turkey wheat brought a final affirmative answer.

Adaptation

Improved adaptation was the chief advance from a plant breeding viewpoint during all of the exploratory and expansion periods. The changes brought about by the introduction of ready-made types suitable for growing in various sections established the wheat industry. Selections or refinement of these new types, which were generally of mixed forms, brought further advance toward a well adapted type of wheat for each locality. Natural selection and the plant breeder's hand took prominent places in bringing these about.

Generally over the wheat belt there has been a progression of varieties, old ones being surpassed by new improved forms, and these in turn yielding to still newer varieties. Bayles and Taylor (8) stated, " Many of the varieties brought to the eastern United States during the Colonial period proved to be poorly adapted and soon disappeared. A few are still grown on a small acreage ". Of the 65 varieties grown in eastern United States at present, less than half a dozen of those in existence 100 years ago are grown today. Poehlman (42) reported that varietal tests covering a 60-year period in Missouri demonstrated successively the higher yielding capacity of Fultz, Fulcaster, Harvest Queen, Michigan Amber and Clarkan. These in turn became leading varieties in Missouri.

In Nebraska and Kansas the greatest change was from spring wheat and soft red winter varieties to Turkey hard red winter wheat. The situation in Nebraska led Kiesselbach (28) to assert that the change to Turkey doubled the acre yield, improved the quality of grain, gave a better distribution of farm labor and provided a high degree of crop insurance for the grower.

Clark and Florell (16) reported experimental evidence in the Pacific Northwest of the good adaptation of Pacific Bluestem, Baart, Federation, Hard Federation and White Federation. In 1941 Suneson and Briggs (56) reported the improvement for California evident in eight varieties which in 19 years of testing surpassed Pacific Bluestem and Big Club by from 26% to 52%.

Thus it may be seen from these examples that improved adaptation, higher yields and more stable production were consequences of growing the new varieties discovered or bred by experiment station scientists and farmers.

The Era of Scientific Wheat Breeding

The real story of wheat improvement starts about 1900 with scientific breeding replacing the chance introduction and the varietal survival methods of the colonial and expansion eras. Clark (14) has told this story so well that a summary of it is all that is needed here. Two basic methods of improving wheat were used, namely (*a*) the single-line selection method, consisting of growing separately the seeds produced by a single plant and treating each such selected plant's progeny as though it were a separate variety, and (*b*) the hybridization method involving cross-breeding two varieties and making single-line selections among the second, third and perhaps later generations of progeny, and a modification of the method called the " backcross ". Clark draws attention to notable progress by the first of these two methods soon after the turn of the century at many State agricultural experiment stations. In Kansas, Kanred hard winter was isolated from a Crimean introduction. In Ohio, Trumbull, Fulhio and Nabob soft red winters were developed. In Minnesota the Haynes Bluestem and Glyndon Fife common spring wheats and Mindum durum were selected. Red Rock soft winter came

out of research in Michigan and Nittany from Pennsylvania. In Nebraska, Cheyenne and Nebraska No. 60 hard winter wheats were bred. Iobred and Iowin were brought out from Iowa work, while in New York Forward, a soft red winter, and Honor, a white winter wheat, were introduced.

The hybridization method has given rise to many varieties. Clark (14) recounts the development of Fulcaster, a soft red winter, by a farmer-breeder in Maryland. Several club wheats, including Hybrid 128, Albit, Hymar and other types, such as Triplet and the bunt-resistant Ridit, were developed in Washington. The development of Marquis spring wheat in Canada marked a great stride forward. Buller (11) estimated the benefits to farmers from the use of Marquis first distributed to farmers in western Canada in 1909 and in quantity to United States farmers in 1912. By 1917 it had gained considerable prominence both in the United States and Canada. In that year, through the replacement of lesser-yielding varieties, Marquis brought a gain in wealth of upwards of 16,000,000 bushels of wheat in Canada and of 10,000,000 bushels in the United States. It was estimated that Marquis was grown on about 44% of the wheat acreage in Minnesota, the Dakotas and Montana in 1917, but this rose to 65% in 1918. It was recognized for many years as the standard of excellence by farmers and millers alike. Use of Marquis in hard red spring wheat breeding in the Dakotas and Minnesota has meant even more to the industry. Marquis is one parent of Hope, Ceres, Thatcher and other varieties. Marquis was used successfully in breeding the hard red winter variety, Tenmarq, grown extensively for a time in Kansas and nearby states.

Most of the varieties released since 1936 were developed by hybridization or by the backcross breeding method. Striking improvements have been made in all classes of wheat. Fourteen major and several minor varieties of hard red winter wheat have recently been developed, according to Reitz and Johnston (47). Among these, Pawnee, Comanche, Triumph and Wichita were grown on three to 11 million acres each in the United States in 1949.

Nature of Wheat Improvements

Wheat varieties have been improved in many ways, such as by increased specific adaptation to local and regional conditions through a good general response to the environment, and by resistance to or escaping from the hazards of production. These attributes come about in the various types of wheat through:

1. Greater yield of grain per acre
2. Earlier maturity
3. Stiffer straw
4. Greater winterhardiness
5. Resistance to rust, smut and other diseases
6. Resistance to hessian fly, sawfly and other insects
7. Non-shattering heads
8. Heavier weight per bushel
9. Improved milling value
10. Higher quality bakery and kitchen products

Such improvements add to the stability of production, make it more economical and increase the potential grain-growing capacity of the farmer. Some evidence to support these claims to improvement will appear in sections which follow.

The Value of New Wheats

Gaines (18) made an analysis of the value of the hybrid wheats produced by the State College of Washington. From 1914 to 1932 the college hybrids—Albit, Triplet, Hybrid 128, Hybrid 123 and Ridit—averaged 18.3% more wheat per acre than the old standard wheats—Jones Fife, Fortyfold, Red Russian and Little Club—that they replaced. Con-

sistently over this period they outyielded the old varieties by 2.1 to 10.3 bushels per acre or an average of 6.3 bushels.

In Washington, Oregon and Idaho, on the above basis (18.3% advantage), Gaines calculated that 70,000,000 bushels less wheat would have been produced in the preceding 25-year period had the old varieties been grown. If instead of 18.3%, a 10% increase is assumed because of possibly poorer adaptation in other parts of the area than was shown at Pullman, the difference would have been a cumulative total of 38,636,000 bushels during the 25 years. At an average price per bushel of 98.5¢ the college hybrids added somewhere between $38,000,000 and $70,000,000 to the wealth of the Pacific Northwest during the 25 years studied. Advantages other than yield were savings in smut loss and reduced winterkilling with the subsequent expense of resowing of such killed-out areas. Also 1.7 pounds per bushel heavier test weight, 1.6% more flour and bread with greater volume and better texture were evident. Stiffer straw and 6% less shattering are other advantages pointed out by Dr. Gaines.

Suneson (55) evaluated nine wheats in California. In 1939, Baart and White Federation occupied 56% of the California acreage, but these varieties were susceptible to bunt and stem rust. In 1944, however, the resistant derived backcross forms, Baart 38 and White Federation 38, occupied nearly 70% of the acreage. This trend was accelerated by State-wide rust damage in 1940 and 1941. At Davis, Calif., in seven tests (six years) when rust was present, Baart and Baart 38 showed averages as follows: stem rust infection, 31 and 1 per cent; test weight, 61.2 and 62.5 pounds; acre yield, 42.6 and 47.5 bushels. The yields were equal in the absence of disease. Considering all of the data, Suneson concluded it was safe to assume an average yield advantage of 160,000 bushels from Baart 38 on its 160,000 acres. A similar increase is likely on the White Federation 38 acreage of 160,000 acres.

Craigie (17) calculated the increased value of rust-resistant varieties in two Provinces of Canada. His findings bear realistically on the situation in the north-central part of the United States.

In Manitoba, from 1938 to 1943, the average difference in production by resistant versus susceptible varieties was estimated at 13,719,000 bushels annually or 5.17 bushels per acre. This was valued at $9,584,000 per year.

In eastern Saskatchewan, from 1939 to 1943, the difference in production showed an average advantage for rust-resistant varieties of 27,620,000 bushels annually valued at $17,658,000 each year. The annual increase averaged 3.0 bushels per acre.

For a 16-year period, had resistant varieties been available, the gain in production would have amounted to 14,123,000 bushels or $16,806,000 per year in Manitoba and 26,878,000 bushels or $30,641,000 each year in eastern Saskatchewan.

From 1916 to 1943 Canada spent about $2,000,000 on rust research. According to the above calculations, farm income improvement in a single year repaid more than 13 times over all the expenditure ever made by Canada on wheat rust research.

Ceres, Thatcher, Rival and Mida are four of the most productive varieties developed in the hard red spring wheat region to be widely grown. Ceres was bred from a cross of Kota by Marquis. Thatcher was from a more complex cross of Iumillo × Marquis by Kanred × Marquis. Rival was from the cross Ceres by Hope × Florence. Mida has a very complex pedigree but has Ceres, Hope and Marquis in its ancestry. Each has been grown on extensive acreages with Mida and Thatcher popular to the present day. Ceres was the first real competitor Marquis ever had, but both gave way

rapidly to Thatcher and Mida. These stem-rust-resisting, strong-strawed, high yielding varieties are truly amazing developments in plant breeding.

One of the first reports on Thatcher came from the originating State of Minnesota (21). Results from six stations showed average gains in yield of Thatcher over Marquis of 6.5, 6.7, 4.4, 2.7, 5.4 and 7.2 bushels per acre. In the severe rust year 1935, fields of Thatcher were islands of normal wheat, producing twice to 25 times as much grain as nearby rust-devastated fields.

Waldron et al. (62) compared the productivity of Ceres and Mida spring wheat with older varieties. Ceres averaged 117.1% of Marquis in a six-year period (62) in 36 experiment station plot yield trials. The advantage accruing to the North Dakota wheat crop during the six-year period because of the new variety amounted to about 7,000,000 bushels. Mida, with greater stem rust and leaf rust resistance than Ceres, Marquis or Thatcher, and good productive capacity has made consistently high yields over a wide region. In the uniform yield nursery in 1939, 1940 and 1941 (46 station-years), Mida averaged 30.5, Thatcher 27.2, Regent 26.0 and Marquis 20.6 bushels per acre. Twenty-six tests in two years in North Dakota gave Mida a 10% greater yield than Thatcher. In Minnesota its four-year average at four stations was 33.4, Pilot 33.8, Newthatch 34.4, Rival 32.1, and Thatcher 28.1. In three years in three Canadian Prairie Provinces it equalled Thatcher in yield.

In another report Waldron (61) pointed out that each successive new wheat variety introduced between 1916 and 1945 resulted in larger yields. The gain over the original Power variety in bushels, due to the introduction of varieties bred for performance, averaged 6.9 bushels at Fargo or about 3.5 bushels on the farm in North Dakota.

In the hard red winter wheat region outstanding increased productivity is evident in new varieties introduced since 1932. A summary prepared by a nine-state committee of wheat research workers (50) gave the grain yield in percent of Turkey for new adapted varieties as follows: Tenmarq, 110; Nebred, 110; Comanche, 130; Pawnee, 132; Wichita, 115; Westar, 125; Marmin, 130; Yogo, 115. In some parts of this area even larger relative increases are indicated. For example, Reitz and Laude (49) reported on 42 tests conducted in Kansas during the years 1937–1942 in which Pawnee averaged 28.4 bushels of grain to the acre compared to 20.0 for Turkey. In percent of Turkey this would be 142%. In further pursuit of this matter, Laude (33) compared wheat varieties at ten experiment stations in Kansas over the ten-year period ending with 1946. The advantage of the best adapted improved variety in percent of extra yield over Turkey was 51 at Manhattan, 46 at Hays, 40 at Garden City, 24 at Colby, 19 at Tribune, 35 at Wichita, 50 at Hutchinson, 21 at Kingman, 31 at Dodge, and 43 at Meade. Since the improved varieties are now planted on most of the acreage in Kansas, Laude estimated that 30,000,000 more bushels of wheat are produced annually than could have been grown on the same acreage from the unimproved varieties.

In an exhaustive study, Salmon et al. (52) tabulated the wheat acreages affected through replacement of old varieties by superior ones and calculated the increases in production resulting from their use. As a basis for the degree of superiority he used the available long-time yield comparisons provided by agricultural experiment station variety tests adjusted to a realistic yield level of the average commercial farm production in each of the principal wheat-growing areas. From this study he concluded that increases in annual production due to new improved varieties in the United States was over 232 million bushels. This was divided as follows:

hard red spring and durum, 101.6 million; hard red winter in the Great Plains, 85.4 million, western states, 23.8 million, and eastern states, 21.0 million bushels. This means that in each recent year, had farmers been limited to those varieties available a half century ago, U.S. wheat production would have been 232 million bushels less than it was.

All estimates referring to what has been accomplished do not imply, necessarily, that such gains can be maintained without continued wheat improvement. Experience has shown that relative varietal responses may be drastically altered by the appearance of a new disease or of a new race of an old disease which places the once superior variety in a susceptible category. Similarly, shifting climatic cycles alter varietal responses on occasion. Finally, it must be admitted that gains in wheat breeding have been offset, in many cases, by declines in soil fertility, so that no actual gain is evident despite the relative advantages of the new varieties over the old ones.

Permanence of Advances in Grain Yield

It is important to know whether new improved varieties maintain their early margin of superiority with respect to relative yielding ability. The increased productivity of superior new varieties is indeed impressive. Experimental evidence presented above seems conclusive, but there has persisted among farmers a general notion that varieties decline in respect to yielding power over a series of years and therefore are progressively of less value as they get older. It is not easy to get evidence on this question. In the first place, a great many years of testing are required, for, if five years are insufficient, will 10 or 20 be adequate? Salmon and Laude (54) and Reitz and Heyne (46) reported results rather typical of data gathered over a 20-year period. Wheat yields and varietal performance vary greatly on farms and in experimental plots, especially in the drier areas. Weather, new diseases, outbreaks of insects and other factors may affect one year's results, or these effects may occur in a cycle of several crop years and establish a new trend in relative varietal performance. Tests, therefore, must embrace a period of years to be representative of conditions in the region where the new variety is to be grown. The results from variety tests already cited in this paper were published in the belief that they fairly represent the requisites of a good test and that they had predictive value for comparable situations. A new set of relationships may come into play under changed conditions that will alter the relative position among established varieties. Salmon (51) showed that a high degree of year × variety interaction exists in variety tests and that this reduces the confidence one can place in short-time varietal comparisons. Suneson (55) noted that superiority in yield of some of the California wheats was demonstrated only in the presence of stem rust. Reitz et al. (48) published data on resistant and susceptible varieties of wheat grown in Kansas and Missouri under three environments, viz., in the absence of severe disease and insect damage, in the presence of stem rust, and in the presence of hessian fly. Resistant varieties gave good performance under all three environments in contrast to the erratic or poor performance of the susceptible varieties when grown in the presence of these hazards. These reports illustrate the limitations of a variety test and show why extreme caution is characteristic of agronomists who make recommendations to farmers. A reversal in average varietal yields for a long period is rare but must be considered a likely result when or if important conditions change.

Laude (32) reported rather fully on nine pairs of varieties grown over a continuous testing period of from 12 to 41 years in a study of data from different wheat-growing areas of the United States. In each case a striking difference in relative yield was shown in the second part of the testing period as compared to the relationship established in the first part, with a reversal in four of the nine cases. It appears that such instances are in the minority, for Laude concludes, " it should not be assumed that a large proportion of variety comparisons show shifts of this kind; in fact, most of them probably do not ".

Many papers have appeared on the question of inconsistency of varietal performance, but one of the most recent by Kiesselbach (29) sums it up by saying ". . . there is nothing mysterious about this behavior. . . . Crop varieties do not ' run out ', but they may sometimes need replacement with new seed for other reasons. The loss of varietal superiority by mixing with other crops, varieties, or weeds, by accidental crossing and segregation, by unfavorable weather and soil conditions, and by disease infections, should be attributed to the true specific causes ".

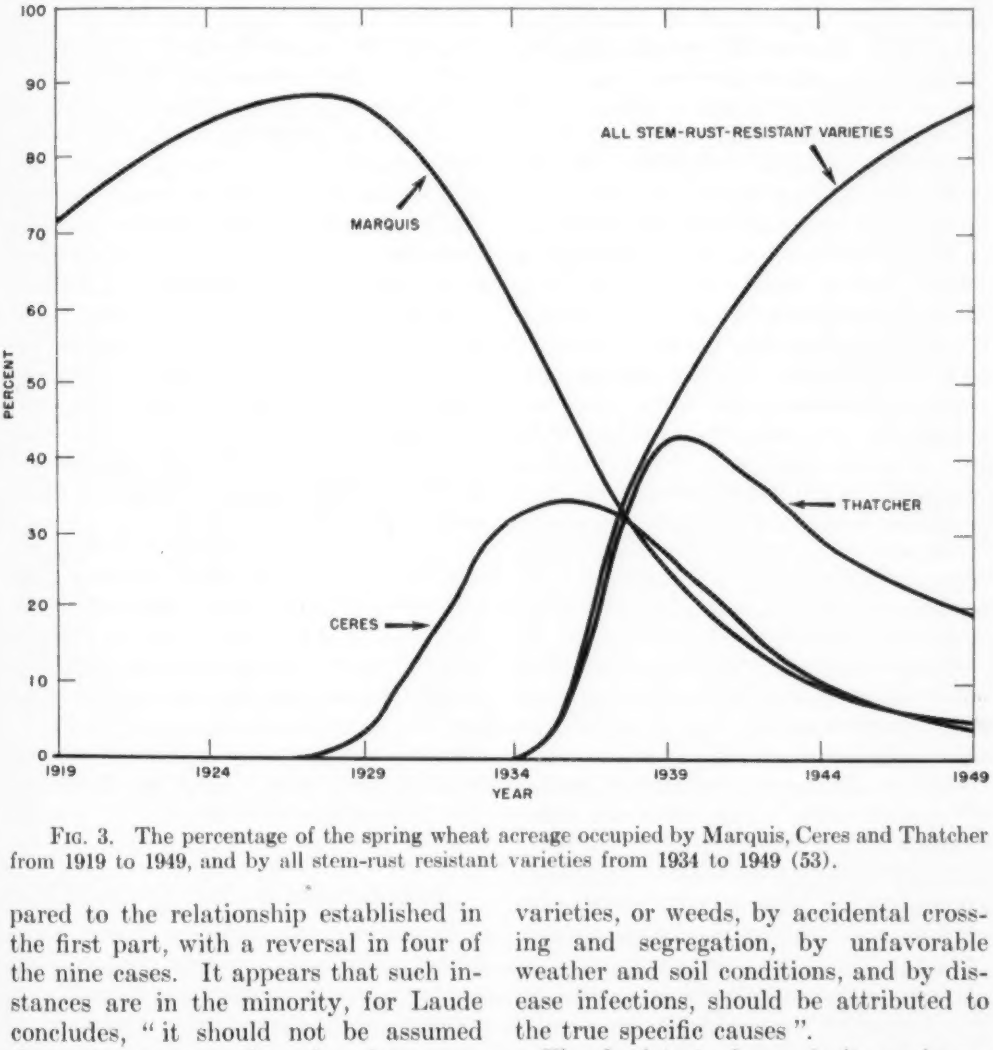

FIG. 3. The percentage of the spring wheat acreage occupied by Marquis, Ceres and Thatcher from 1919 to 1949, and by all stem-rust resistant varieties from 1934 to 1949 (53).

The final test of superiority and permanence comes from the extent to which new varieties are grown with profit by farmers over a long period and the general yield trend in various parts of the

wheat-growing area. The extent of variety acceptance was brought out clearly by Salmon and Bayles (53) in a review of changes in the last 35 years. Of the 200 or so different varieties of wheat grown on farms in the United States in 1949, 118 were bred at experiment stations in North America in the past 35 years. Their combined acreage amounted to about 76% of the total of all wheat. One of their graphs (Fig. 3), shows the marked early acceptance of Marquis spring wheat followed by nearly complete replacement of it by stem rust resistant varieties. In the durum wheat area Stewart and Carleton, of no great importance before 1944, accounted for half of the durum acreage in 1949. Turkey hard winter wheat, once about the only significant variety of this class, gave three-fourths of its acreage to Kanred, Blackhull, Tenmarq and miscellaneous varieties by 1944. Pawnee, Comanche, Triumph, Wichita and Westar, scarcely known in 1944, claimed over 60% of the total acreage by 1949. A similar swing to new varieties is shown in the soft red winter and western wheat regions. Performance, not publicity, is responsible for such rapid and widespread acceptance.

Those who study national per-acre grain yields have looked for a general rise as the superior yielding varieties have come into use. No clearly defined trends are apparent. Following a period of rising yields from 1916 to 1931, drought and rust caused lower yields in the '30's. A new high level of yields was reached in the '40's and early '50's. In view of the shift in the wheat acreage from areas of high to lower rainfall (Fig. 2) and a general decline in soil fertility, it is surprising that the yield level could be maintained at all. Some evidence indicates that it has actually increased. Heisig et al. (22) made a careful study of this problem. Yields in the specialized wheat-growing areas fluctuated primarily because of variations in amount of rainfall, although other factors such as temperature and disease damage were important. By the use of an adjusted yield based on the net regression of yield on " time ", with precipitation and mean temperatures for selected months held constant, yield trends were separated to a considerable degree from fluctuations due mainly to major weather effects. Application of this technic to yields in North Dakota and Kansas for the years 1919 to 1944 revealed a trend of adjusted yields three to four bushels higher at the close of the period. This represents progress equivalent to an increase of 25% to 30% in the average yields of those two states. Unadjusted data indicate that similar increases, or greater, have come about in the last 25 years in the southeastern States, the soft wheat belt and the Pacific Northwest. Increased per-acre yields are credited to widespread adoption of improved varieties, better methods of disease and insect control, increased use of summer fallow and other improved management and conservation practices.

In an over-all review of cereal research, Quisenberry (44) calculated that the increase in the wheat crop is 200 million bushels per year. This is due in large part to more productive varieties.

All tax-supported agricultural research in the United States totals about $110,000,000 annually. Thus the increased income from wheat alone at $2.00 per bushel would return four-fold the annual cost of all agricultural research.

Improvement in Plant Characters

In addition to yielding ability, a number of plant characters are of great importance in determining the success of a variety of wheat. Some varieties of nominal yielding ability are justly popular with farmers because of such plant characters as short stiff straw, non-shattering grain, heavy weight per bushel, early maturity and winterhardiness.

With the advent of the combine-har-

vester, stiff straw and non-shattering of grain became extremely important, and breeding for these characters was emphasized. Considerable success in all areas has been achieved. The Pacific Northwest and California wheats—Elgin, Alicel, Elmar, Brevor, Orfed, Poso, White Federation and Hard Federation —usually grow six to ten inches shorter than older varieties. These varieties also have stiff straw and resist lodging. Among hard red spring wheats, Lee, Rushmore and Thatcher grow several inches shorter than Rival, Pilot, Mida and Marquis. Among soft red winter wheats, Early Premium, Purcam and possibly Thorne, are examples of varieties with short stiff straw. Pawnee and Triumph are perhaps the outstanding examples of short-strawed hard red winter wheats. They commonly measure three to six inches shorter than Tenmarq, Turkey or Red Chief. Length and stiffness of straw are not always correlated; hence observations on one character do not assure excellence in the other. Some tall or mid-tall varieties such as Cheyenne and Red Chief are among the stiffest strawed hard red winter varieties grown in the Central Plains.

Considerable progress in breeding non-shattering western wheats has been made **(60)**, and the Blackhull group of hard red winter varieties shatter little **(23)**. In other areas, and in other groups of hard red winter wheat, only slight progress has been made in improving this character by breeding during the past 50 years. Most of the varieties are acceptable, but further breeding work is needed to improve the grain-holding qualities of the wheat spike.

Heavier weight per bushel has been achieved in many varieties. Waldron et al. **(62)** reported that Mida averaged 60.8 pounds to the bushel compared with a 57.8-pound average made by three other spring wheats grown in 41 tests in North Dakota. The Blackhull group of winter wheat varieties and Wichita regularly exceed Turkey by 1.5 to 4 pounds per bushel **(23)**.

Early maturity bred into varieties of spring wheat permits the crop to ripen most years before frost in northern States. In the hard winter wheat belt this character bred into new varieties enables the crop to develop before the hottest part of the summer arrives, and earliness often provides for partial escape from rust damage. The trend toward earlier varieties in this area started with the first breeding work and continued for 35 years. It appears now that the earliness of Triumph (two weeks earlier than Turkey) is the limit beyond which breeders should not go.

Winterhardiness in fall-sown varieties is of utmost importance. During the period 1901–1928 an average of nearly 11% of the total winter-wheat acreage of the United States was abandoned annually, largely because of winterkilling **(45)**.

Winter injury may be reduced by growing hardy varieties and by using proper cultural practices. Among hardy varieties capable of a high grain yield are Minturki, Minter and Yogo. Other hardy varieties, Buffum No. 17 and Minhardi, are relatively low yielding. Minturki and Yogo survived one-fifth better and yielded about 10% more grain than Kharkof, whereas Buffum No. 17 and Minhardi survived one-fourth better but yielded about 15% less grain than Kharkof. These results were obtained in four to ten years of testing at nine to 21 stations each year in a regional uniform winterhardiness nursery. Progress was reviewed by Quisenberry **(43)**, Bayles and Taylor **(7)**, and Ausemus and Bamberg **(4)**. Their findings established the varying nature of the hardiness problem, calling for somewhat different kinds of winterhardiness in various parts of the wheat-growing area. The most cold-enduring varieties appear to include Yogo, Minturki, Minhardi,

Marmin and Minter, but less cold hardy varieties often survive better under conditions of soil heaving. It appears possible to combine these types of winterhardiness. The development of productive hardy varieties has had a great influence on the successful production of winter wheat in the northern fringe of the winter wheat region.

Disease Resistance

Breeding for disease resistance has provided some of the most striking examples of economic benefit from wheat breeding. Diseases cause loss every year, and the problems of disease control are far from being solved. Some diseases are so destructive and difficult to control by other means that successful wheat production often depends on inherent resistance bred into the wheat plant.

The important diseases of wheat as given by Ausemus (3) are black stem rust (*Puccinia graminis tritici* Eriks. and Henn.), orange leaf rust (*Puccinia triticina* Eriks.), yellow stripe rust (*Puccinia glumarum* (Schu.), Eriks. and Henn.), stinking smut (*Tilletia tritici* (Bjerk.) and *T. levis* (Kuhn)), loose smut (*Ustilago tritici* (Pers.) Rostr.), and scab (*Gibberella saubinetti* (Mont.) Sacc.). Other destructive diseases are the root rots, black chaff, and viruses or mosaics. Leaf blotch and spots, mildew and stem rotting organisms (*Septoria* spp.) sometimes appear serious.

In his review Ausemus pointed out the importance of growing varieties of wheat resistant to stem rust. In 1904 and 1916 stem rust took a toll each year of 100 million bushels of grain in the United States. Severe losses occurred in 1919, 1920, 1921, 1923, 1927, 1935 and 1937 with measurable losses in other years. Several varieties possessing resistance to a few races of stem rust were discovered by plant scientists and utilized by plant breeders. There resulted a series of releases with limited effect on rust losses, including Kanred winter wheat (1917) and the spring wheats Marquillo (1928), Kota (1920) and Ceres (1927). Kanred and Ceres were grown extensively, but other races to which they were susceptible became prevalent and severe injury from stem rust was again experienced. Hope (1926) and H44 (never released), developed by McFadden, were the result of selections from the cross Yaroslav emmer × Marquis. These varieties had very high resistance to stem rust and were used extensively in breeding the high yielding and high quality varieties Pilot, Rival, Renown, Regent and others which became available during the late 30's. Thatcher, combining resistance mainly from Kanred and a durum wheat, was released in 1934. Mida was from a complex hybrid having Ceres, Hope, Kanred, Marquis and durum ancestry. It was released in 1944 and became the leading variety of hard red spring wheat grown in the United States in 1949, according to Clark and Bayles (15). These and other varieties quickly became established, and during the period 1938 to 1949 there was virtually no economic loss from stem rust where they were grown.

A new race of stem rust called 15B became prevalent in 1950, to which all of these varieties are susceptible so the plant breeder's battle must be fought over again. Resistant parental stock is known and hybrids with good commercial wheats are in advanced generations. Selkirk, developed in Canada, and Willet, developed in Minnesota in cooperation with the U. S. Department of Agriculture, are the first 15B resistant hard red spring wheats to be named for growing in the Northern Plains. Travis and Bowie are newly named 15B resistant intermediate winter wheats developed in Texas in cooperation with the U. S. Department of Agriculture for central Texas.

Stem rust resistance has been bred into

several varieties of wheat of classes other than the hard red springs mentioned above. Of note are Stewart and Carleton durum from the cross Vernal emmer by Mindum backcrossed to Mindum. Also by backcrossing, several improved California wheats, such as Baart 38 and White Federation 38 already mentioned (55), have been bred for the Hope type of resistance to stem rust. In the central and southern Plains only limited success has been experienced, using Hope for resistance mainly because of physiological weaknesses rather regularly transmitted to winter wheats along with the rust resistance. Most serious has been the susceptibility to heat and drought shown by resistant lines when grown in these areas. Of the commercial releases, Quanah for eastern Texas seems to be the best, although it too suffers from drought and temperature extremes (2). Minter is a very winter hardy variety bred in Minnesota from a Hope × Minturki backcross. Early maturity bred into central and southern Plains hard red winter wheats has given a large measure of escape in this area, but its advantage diminishes northward. Pawnee, Comanche and Triumph, leading varieties of this class in 1949, head and ripen seven to 14 days earlier than Turkey, thereby avoiding one or possibly two propagation cycles of the rust fungus.

Leaf rust is less dramatic than stem rust but causes some loss nearly every year. It may cause complete loss of the crop, although such extreme damage is rare. Many races of leaf rust occur which complicate the breeding problem. Johnston et al. (25) reported 48 races identified during the six-year period 1938–43 from collections made on wheat grown in uniform rust nurseries in the United States. Race 9 was the most common, followed in order by races 15, 76, 126, 44 and 5. Lee, Atlas, Quanah and Ponca are new varieties with excellent resistance to many races. The older varieties continued to show resistance until races to which they were susceptible built up. After this happened, a part of their superiority was nullified. Resistance to more races is now being bred into wheat varieties for all areas where this disease is important.

Stinking smut causes loss to the farmer by reducing both the yield and market value of the grain. Kiesselbach and Lyness (30) found a correlation coefficient between grain yield and smut percentage of $-.919 \pm .014$ in 54 trials at Lincoln, Nebr. An average of 25.8% of smutted heads during nine years was accompanied by an average decrease in grain yield of 22.8%. Morris and Schlehuber (38) found in a test with three varieties at Bozeman, Mont., that as the smut percentage increased from 5.0 to 14.2 to 40.9, the grain yield decreased correspondingly from 92.0 to 84.0 to 61.3 bushels per acre. Tingey and Woodward (58) of Utah stated that during the period 1924 to 1933 losses from stinking smut of wheat averaged 7.1%. Carlots at the Ogden market ranged from 20.2% smutty in 1924 to a peak in 1929 of 46.5% followed by a decline to 17.0% by 1933. Relief was released by these workers for commercial growing in 1931. Breeding smut-resistant varieties is the most helpful solution to such a problem. Relief is resistant to many races of common bunt and is also quite resistant to dwarf bunt, a race that lives over in the soil and against which seed treatment has been ineffective. It is equal to Turkey in most agronomic and quality characters.

Holton and Suneson (24) made a study of smut in the western wheat region. Prevalence of smut varied with locality, season, type of wheat (winter more than spring) and variety. The percentage of carlots of wheat grading smutty at North-Pacific inspection points from 1922 to 1940 showed a general de-

cline from 43.7, 41.5 and 50.4%, respectively, in the first three crop years of the period to 7.6, 5.6 and 8.6% for the last three crop years and dropped to 3% in 1942. This seemed correlated with the use of copper carbonate dust for smut control which began about 1922, followed by other effective seed disinfectants and widespread use of resistant varieties. Among resistant varieties mentioned, and the year of release, were Ridit (1924), Sherman (1926), Oro (1927), Albit (1927), Rio (1930), Relief (1931), Yogo (1933), Rex (1933) and Hymar (1935). The improved red winter varieties Cache and Wasatch were released in 1937 and 1942, respectively, in the Pacific Northwest to combat the dwarf bunt disease. Orfed, Elmar and Brevor are new white wheats with resistance to dwarf bunt. Since 1942 there has been another upsurge of smut in this area such that in 1950, 30.6% of the shipments of wheat in the Pacific Northwest were degraded because of smut (53). This is associated with the decline in acreage of Rex due to poor milling quality and the widespread use in recent years of the smut-susceptible wheat varieties Alicel, Elgin and Golden which have high yield and good agronomic characters. It should not be difficult to breed smut resistance into such varieties barring the advent of new races. Briggs and Holton (10) have shown that two major genes, *T* and *M*, derived from the Turkey and Martin varieties of wheat give resistance to all of the races and also to dwarf smut. Several minor genes were discovered which gave resistance to certain races or race groups.

Melchers (36) reviewed 35 years of experience with stinking smut in Kansas wheat. After effective chemicals became available, losses declined steadily from a high point of 10% loss from smut in 1926 to less than 0.5% loss in every year save one since 1935. Resistant varieties in recent years have added to the effectiveness of smut control. Johnston et al. (26) gave results on 155 varieties and strains of hard red winter wheat tested in uniform smut nurseries. Varieties commercially grown having effective resistance where adapted were Comanche, Pawnee, Nebred, Oro, Ridit, Rio, Minturki, Marmin, Yogo, Minter, Relief, Cache and Wasatch. Martin and selections from Turkey provided most of the basic resistance in these varieties.

Loose smut causes loss to the farmer in lower yield of grain as the heads are destroyed by the fungus, but market quality of the grain is not noticeably impaired. Loose smut is common in wheat in all areas but tends to be more prominent in areas of high humidity. It is unusual to find more than five percent of smutted plants in a field of wheat, although numerous cases of infection of 10% or more have been reported. Wingard and Fromme (63) found marked resistance to the disease in Leap, a soft red winter wheat of importance in Virginia and nearby States. They also found resistance in pure line selections of Fulcaster, Fultz and Poole, although the parent varieties Fultz and Poole generally proved susceptible. Also resistant were Kawvale, Trumbull, Forward, Leapland, Mediterranean, Fulhio and other varieties. Atkins (1), in a four-year test at Denton, Texas, confirmed the findings of other workers on the resistance of several varieties but got quite different results with a few apparently because different races were present in the inoculum used. He found the varieties Pawnee, Kawvale, Forward, Purdue No. 4, Leap, Zimmerman, Purplestraw, Early Premium and Minhardi and a large number of Hope × Mediterranean selections to be resistant. Bever (9) has keyed out the races of this smut. It is apparent that factors for resistance are present in several classes of wheat, but farm losses continue on several million acres because susceptible varieties of wheat claim a large acreage. In the spring wheat belt a larger acreage of sus-

ceptible varieties is grown now than formerly.

Mosaic or virus diseases of wheat are rather widespread and of several different sorts. McKinney (35) described seven, but other sorts exist. Total destruction of wheat by mosaic has been observed in areas east of the Mississippi River and in the center of the hard red winter wheat belt (37). Satisfactory control of the mosaic-rosette virus east of the Mississippi River has come from the use of resistant varieties. Koehler et al. (31) stated that if resistant varieties had not been found, wheat would rarely be grown in parts of Illinois where it is now an important crop. It is hoped that similar resistance can be found as protection against other types.

Scab or head blight has been one of the destructive diseases of wheat in the corn-growing area of the spring wheat region of the Upper Mississippi Valley. Varieties give rather confusing results over a series of years so far as resistance is concerned. After several years of carefully controlled experiments, Hanson et al. (20) found considerable evidence of varietal differences among spring wheats, but none was highly resistant under all conditions. Progress, Haynes Bluestem, Cadet and Rival were among the most resistant wheats studied. Reward, Renown, Regent and Newthatch were extremely susceptible. Mida was intermediate, somewhat below Ceres and Marquis in infection. Early maturing varieties showed more blight than late ones.

These examples of plant breeding effort to control diseases are not complete accounts by any means, but they serve to establish the fact of substantial progress in some areas and the equally striking fact that the job is only partially completed.

Insect Resistance

Perhaps the most important insects attacking wheat are the hessian fly (*Phytophaga destructor* Say), the wheat stem sawfly (*Cephus cinctus* Nort.), several species of grasshoppers, the greenbug (*Toxoptera graminum* Rond.) and the chinch bug (*Blissus leucopterus* Say). A host of other species are of local importance.

Painter (39), in a comprehensive survey of published literature on the subject, found that the major studies on resistance in wheat have concerned the hessian fly and sawfly. Resistance or varietal differences in susceptibility to at least 13 additional species or groups of insects was established.

The hessian fly attacks wheat in all of the important producing regions of the United States. It has been the object of a great deal of study. Thousands of selections and varieties have been observed in the long search for resistance. Very effective resistance has been discovered and is being bred into commercially adapted types. The most striking economic success to date has been in Kansas and California, although work in several other States has been or soon will be felt. Levels of resistance and tolerance range from a slight tolerance to immunity. Although several races of the insect are recognized, high resistance to each race has been found (13).

Suneson and Noble (57) told about breeding Poso 42 and Big Club 43 in California. This involved the transference of two dominant genes for resistance from Dawson by the backcross method. This breeding program has now been completed, and the wheat acreage in the area has been taken over by the derived resistant varieties. The resultant destruction of natural infestation precludes further inheritance studies under field conditions in this location.

Painter and Jones (41) gave evidence from test nurseries and farm plantings in Kansas of the fly resistance of Pawnee. Fifty-eight farm fields of Pawnee in 1947 averaged 8% fly, whereas 62 adjacent fields of susceptible varieties

averaged 25% infestation. In 19 of 23 counties in 1946–47 the environmental conditions appeared favorable for fly, but a decrease in fly infestation actually occurred. In this year Pawnee occupied about one-fourth of the acreage of this area of central Kansas. These same authors (40) stated that in cooperative experiments in 1941, '42 and '43 on farms in central and eastern Kansas where fly was present, Pawnee showed an advantage over Tenmarq in all but three of 26 paired plots. The advantage in yield of Pawnee over Tenmarq in these plots in terms of the Tenmarq yield was under 20% nine times, 20 to 74% 13 times, and 75 to 133% four times. Yield differences in the absence of fly gave a yield advantage to Pawnee of 17% in the same area and period of years.

Finally, Painter (39) concluded that "it should be noted that 25 years after the first crosses were made between fly-resistant and fly-susceptible wheats, new varieties carrying these resistant characters were being distributed to farmers. Thirty years after the first crosses were made these fly-resistant wheats . . . were being grown on several millions of acres". A still higher level of resistance among commercial hard red winter wheats is represented in the Ponca variety that was released in 1951 in Kansas and Oklahoma (34).

The sawfly damages wheat principally in Montana, North Dakota and adjacent areas in Canada. In 1952 it was reported in wheat as far south as Nebraska. It infests the stems of several grasses and some other plants. Kemp (27) in Canada reported resistance among wheat varieties having solid or semisolid straw. This and other work in Canada called attention to the resistance of Golden Ball durum and the common spring wheats S-615 and S-633 (39). These varieties were not acceptable for culture, so breeding work was started. One result was Rescue, released to Canadian farmers in 1947 and in Montana also the same year. It was a selection from a cross of Apex and S-615. Rescue is only moderately resistant in some localities, does not yield so well as certain other varieties in the absence of sawfly, and is somewhat deficient in flour quality; hence, further breeding is needed. In the meantime the protection given by Rescue is of considerable value to farmers who sow a million or more acres of it a year. Active research is being conducted in North Dakota and Montana by the U. S. Department of Agriculture and State experiment stations to discover better resistance and to develop superior varieties.

Resistance to several other insects has been reported and undoubtedly contributes to the success of growing wheat where these insects occur. Painter (39) emphasized the possibilities of enhancing varietal resistance by further breeding. Extensive work in some cases is being done on the greenbug in Oklahoma and Texas, on jointworm and wheat-stem maggot in Kansas and Indiana, and on grasshoppers in North and South Dakota, although work is not entirely confined to the States named.

Quality

Varieties of wheat fall into market classes according to where they are grown and the use for which the flour from each is best suited. Hard red winter and hard red spring wheats are milled into flour for bakery or home use to make light bread. The durum wheats are specially suited for macaroni and similar products. The soft red winter varieties are for cake and pastry, crackers, breakfast cereals and other products. Some interchanging is possible if the protein levels and kernel textures are right for the end-product in mind.

Wheat breeding has followed the dictates of the market demand. Geddes (19) stated that "today, no reputable

wheat breeder would consider releasing a new variety without exhaustive milling and baking tests; in short, the combined skills and technics of the geneticist and the cereal chemist are required to bring any wheat-breeding program to a successful outcome ".

The extent of improvement in quality cannot be expressed in a few statements. However, when variety adaptation is improved, a crop of better quality results; when stinking smut is controlled, less wheat is wasted and a superior product can be milled; when the breeder and cereal chemist work together, the variety thus produced will fit a known market need and will not have to find its place by chance. Varieties with adverse market qualities are rapidly being replaced by those having acceptable characteristics, and in several cases new levels of market superiority are indicated.

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Stimulation of Pine Oleoresin Flow by Fungus Inoculation

Since the early 1930's it has been known that application of certain chemicals to tapping surfaces on pine trees will stimulate the flow of oleoresin, and industrial use of a 50% sulphuric acid spray for this purpose is increasing. Now, investigations, discussed here, indicate that some stimulation may be achieved by inoculation with a fungus.

RUSSELL B. CLAPPER [1]

Introduction

Pine oleoresin is extracted from turpentine pines in this country by two methods. Wood chipping, the older and more common method, consists of chipping on the trunk of a tree a horizontal or slanting streak to a depth of one-half inch in the wood. One streak is chipped each week on each tree. The other method, bark chipping with acid treatment (5, 6), was developed and introduced to the naval stores industry by the Southeastern Forest Experiment Station at Lake City, Florida. The bark only is chipped, to the cambial layer, and the streak is one-half inch high, the same as a wood-chipped streak. The streak is sprayed with a 50 percent solution of sulphuric acid. The acid stimulates the flow of oleoresin, so that a single streak with treatment is required only every two weeks.

The bark-chipping-with-acid method is superior to wood chipping because it is less injurious to the trees, and it produces more oleoresin with less labor. The acid, however, is corrosive to the skin and clothes of the chippers. The Southeastern Forest Experiment Station at Lake City is seeking other chemicals that stimulate oleoresin flow and that are safer to handle.

Investigations made by the Division of Forest Pathology at Asheville, North Carolina, showed that a fungus, parasitic to turpentine pines, stimulated oleoresin flow when inoculated into the streaks on their trunks. This report presents the results of additional investigations, made in Florida, on stimulating oleoresin flow and on inducing pitch soaking of wood of turpentine pines by use of the fungus. The fungus was inoculated at different times into different types of wounds on the turpentine pines to determine which procedure would yield the most oleoresin. Later tests included standard acid-treated bark chipping and wood chipping so that yields from the fungus treatments could be compared with those from the standard treatments.

Discovery and Preliminary Investigations of the Pitch-Canker Fungus

Hepting and Roth (2) reported a species of *Fusarium* causing very pitchy cankers on young branches and stems of

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The author expresses his appreciation for the advice and guidance given by Dr. George H. Hepting, under whose direction this work was conducted in cooperation with the Southeastern Forest Experiment Station, Lake City, Florida; for the assistance and unpublished data furnished by Dr. R. P. True; and for the assistance of Mr. Milton M. Smucker in preparing the trees used in the tests.

Virginia pine (*Pinus virginiana* Mill.) and, to a lesser extent, on those of shortleaf pine (*P. echinata* Mill.) and pitch pine (*P. rigida* Mill.) (Figure 1). The pitch-canker fungus was named *Fusarium lateritium* f. *pini* (7). Surveys for pitch canker showed that it is widely distributed from northern Virginia to southern Florida and westward to Mississippi, and that the disease occurs principally on Virginia pine, the common slash pine (*P. elliottii* Engelm.), south Florida slash pine (*P. elliottii* var. *densa* Little & Dorman) (3), and longleaf pine (*P. palustris* Mill.).

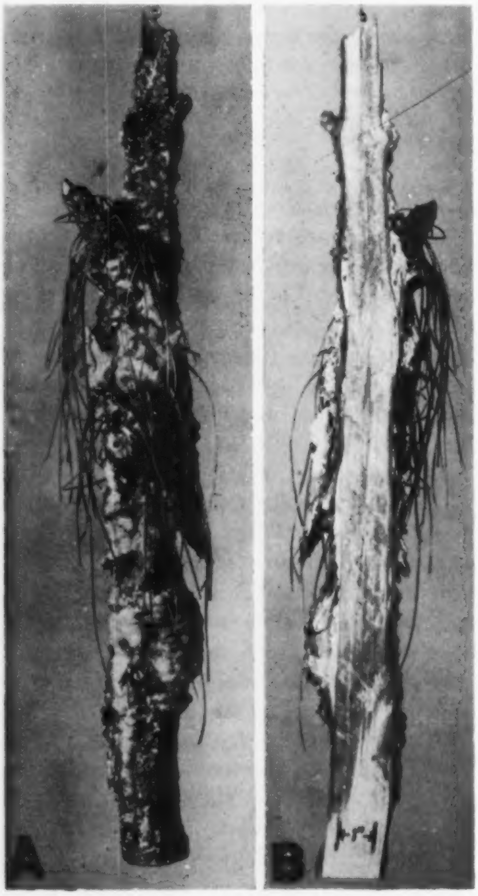


FIG. 1. A, Pitch canker on slash pine. B, Crystallized gum and pitch-soaked wood are usually associated with these cankers.

Hepting (1) inoculated the pitch-canker fungus into artificial wounds on longleaf, Virginia and shortleaf pines, and obtained marked stimulation of oleoresin flow, particularly from longleaf pine. On February 17, 1948, he was granted a public patent (No. 2,436,359) that covers methods and processes of obtaining increased production of oleoresins from coniferous trees, and of stimulating the infiltration of oleoresin into the wood of living trees, by application of the pitch-canker fungus to wounds.

True and Snow reported (8) results of their preliminary investigations on stimulating gum [2] flow by inoculating the pitch-canker fungus into slash and longleaf pines at Olustee, Florida. The first, or virgin, streaks on these pines treated with a water suspension of spores of the fungus [3] prolonged the flow of gum at commercial rates from slash pine to five weeks and from longleaf pine to three weeks, whereas the untreated streaks flowed gum for one week. Rechipping and reinoculating the same faces prolonged the flow of gum from slash pine for three weeks and from longleaf pine for two weeks.

In 1948 True conducted gum-flow stimulation tests on loblolly (*P. taeda* L.) and sand pines (*P. clausa* (Engelm.)

[2] Although the exudate from turpentine pines is an oleoresin, in the naval stores industry it is commonly called "gum". Wood that is infiltrated with oleoresin is commonly described as being "pitch soaked".

[3] The spore suspension used by True and Snow and by other investigators is made as follows: The fungus is grown on potato sucrose agar in Petri dishes for a week or ten days. Sterile water is poured on top of the cultures, and the microspores are dislodged into the water by stirring with a camel's hair brush. The water containing the suspended spores is collected from several Petri-dish cultures and placed in a plastic squeeze bottle after filtering through cheesecloth. This spore suspension is sprayed from the bottle onto the freshly cut streaks or other types of wounds on the tree.

Vasey) on the Ocala National Forest. Ten trees of each species were used. Loblolly pine, which is not exploited commercially for its gum, when inoculated yielded 106 grams of gum per tree for the first week compared with 42 grams from the wood-chipped, untreated check trees. Rechipped and reinoculated faces yielded much less gum. Sand pine when inoculated yielded 38 grams of gum per tree the first week compared with 21 grams for the check trees. Pitch soak behind the fungus-treated faces extended to a depth of one and one-half inches in loblolly and one inch in sand pine. The stimulation of gum flow in these species is remarkable, since neither apparently is a natural host for the pitch-canker fungus.

Inoculation Tests with the Pitch-Canker Fungus

Period of Gum Flow. This test was initiated and conducted by True in 1948 and concluded by the author in 1949. It was designed to show the relative importance of season on gum yields, to determine the effect of previous chipping with inoculation on gum yields from subsequent chippings with inoculations, and to determine the effect on yields of multiple faces on the trunks of pine trees. All streaks were wood-chipped and inoculated with the *Fusarium*.

TABLE I

AVERAGE YIELDS OF GUM FROM INOCULATED VIRGIN STREAKS AND RECHIPPINGS OF FOUR FACES[1] ON SLASH PINES

Type of streak	Yield of gum per week			
	Face A	Face B	Face C	Face D
	gms.	*gms.*	*gms.*	*gms.*
Virgin streaks	92	85	75	58
1st rechipping	70	58	47	49
2nd rechipping	51	43	39	50
3rd rechipping	47	45	47	62

[1] Tests 1 to 4, April 5, 1948, to June 20, 1949.

Eighty slash pines were divided into eight lots of ten trees each. All ten trees of a lot received the same chipping and inoculation treatment. The lots were treated in sequence with a time lapse of five to nine weeks between treatments. A new lot of trees was treated when gum yields from the preceding lot were considered commercially inadequate.

On April 5, 1948, each of the ten trees of Lot 1 was given a six-inch streak (the virgin streak), one-half inch high and one-half inch deep. Each streak was inoculated with a spore suspension of the pitch-canker fungus. No further chipping was done until May 10, when the flow of gum from Lot 1 trees was less than adequate. The virgin faces (A faces) were then chipped into clear wood,

TABLE II

AVERAGE YIELDS OF GUM FROM INOCULATED VIRGIN STREAKS AND RECHIPPINGS OF FOUR FACES ON SLASH PINES[1], BY PERIODS OF FLOW

Type of streak	Average yield of gum per week						
	4/5/48 to 5/10/48	5/10/48 to 7/7/48	7/7/48 to 8/23/48	8/23/48 to 10/18/48	10/18/48 to 12/13/48	12/13/48 to 2/14/49	2/14/49 to 4/11/49
	gms.	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*
Virgin streak	88 A[2]	102 B	92 C	86 D	....	....	....
1st rechipping ...	....	80 A	66 B	47 C	52 D	....	....
2nd rechipping ...	....	.....	47 A	44 B	40 C	41 D	....
3rd rechipping ...	....	.....	....	46 A	50 B	43 C	48 D

[1] Test 1, duration 53 weeks.
[2] The letters refer to the four faces of each tree.

and the new streaks, or rechippings, were inoculated. Also on May 10 a second six-inch face (B face) was chipped and inoculated on each tree of Lot 1, and a new series of A faces was chipped and inoculated on each of the trees of Lot 2. Periodically new lots of trees were thus brought into the test, and the number of faces per tree was increased to four (designated A, B, C, D). After a face was rechipped and reinoculated a third time, it was no longer worked.

The test was terminated on June 20, 1949, when the flow of gum from the several lots, and from season to season, showed similar patterns. The results from the first four lots of trees are presented, since the last four lots were not completely treated.

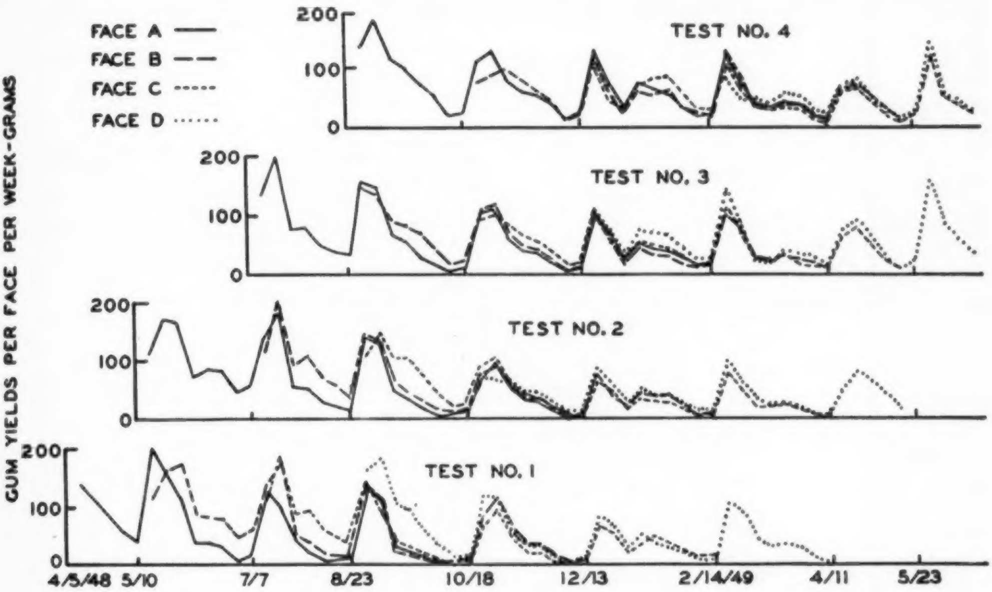
Gum flowed from the inoculated streaks for five to nine weeks, the most frequent period being eight weeks. The highest yield of gum occurred during the first week after chipping and inoculating, and it was usually higher from virgin streaks than from subsequent streaks. Also, gum yields were higher from the first face than from the following faces on a tree. (Table I and Figure 2). Gum yields by period of flow declined as winter approached (Table II and Figure 2) but tended to rise again with the approach of warm weather.

The period flow test was also a multiple face test and was unusually severe in that two-thirds or more of the circumference of trees nine to 12 inches d.b.h. were wounded to a depth of one-half inch, and these wounds were inoculated with the pitch-canker fungus, a parasite on the branches and upper stems of slash pines. Despite such treatment, no typical pitch cankers developed on the trunks, and none of the 80 trees was lost from treatment with the fungus. However, one tree died because of too-narrow bark bars between the faces.

Bark-Chipped versus Wood-Chipped Streaks. Other tests showed that inoculated bark-chipped streaks one and one-half inches high yielded larger amounts of gum than streaks of less height. To compare gum yield from inoculated one and one-half inch bark-chipped streaks made biweekly with yield from inoculated wood-chipped streaks, two standard wood-chipped streaks were made biweekly, so that the frequency of chipping would be the same for the two treatments. Forty longleaf pines were used, 20 trees for each of the two treatments. The test was started in the spring of 1949 and was continued for 31 weeks, one week short of the standard season.

Cumulative yields of gum from the inoculated double wood-chipped trees surpassed yields from the inoculated bark-chipped trees throughout the test (Figure 3). Also shown in this figure are cumulative yields from standard wood-chipped and from standard acid-treated trees. The standard acid treatment of faces now being adopted by the gum industry involves making a bark-chipped streak one-half inch high every two weeks, and spraying the streak with a 50 percent solution of sulphuric acid. For the first several weeks, gum yields from fungus-treated faces approximately equalled yields from acid-treated faces, then yields from the fungus-treated faces steadily diminished.

The crystallized gum, called " scrape ", that accumulates on faces is collected at the end of the gum season. Fungus-treated faces produced less scrape than standard wood-chipped and standard acid-treated faces. Gum from inoculated faces crystallized less rapidly, and this may explain why these faces had less scrape than acid-treated and untreated faces. The difference between total yields of gum and scrape from fungus-treated faces and total yields from standard acid and wood-chipped faces is therefore greater than the difference between gum yields alone (Table III).



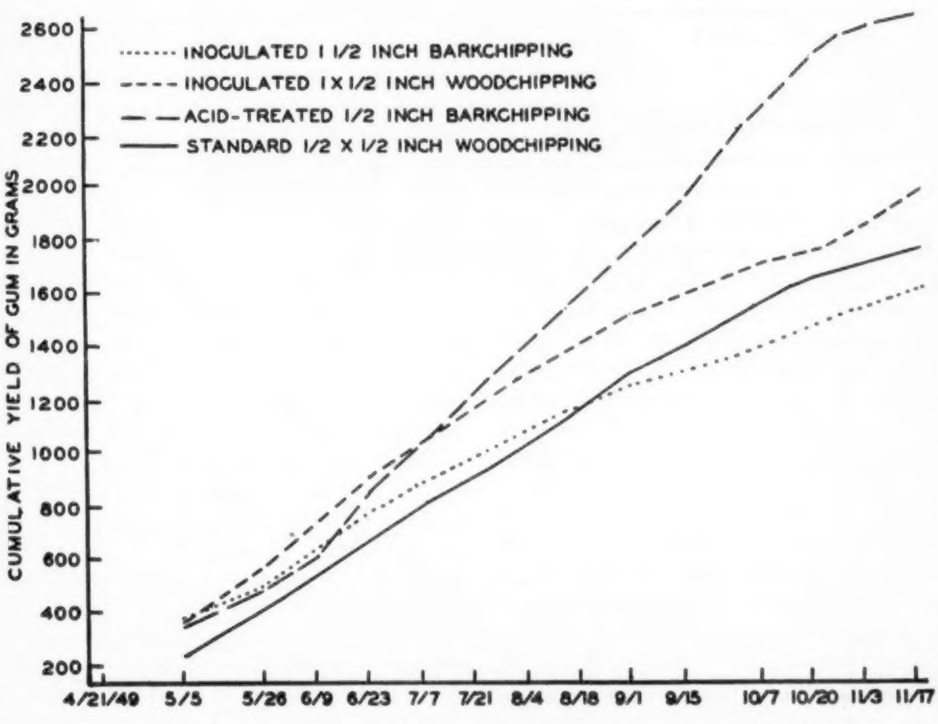
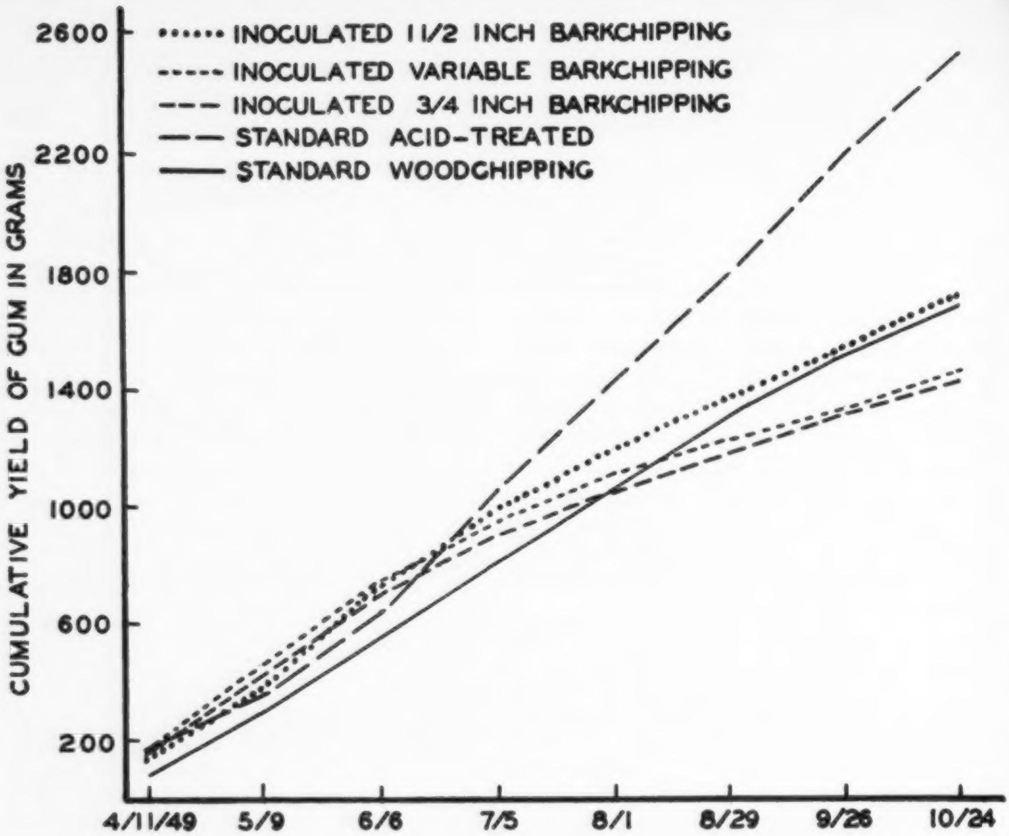


FIG. 2 (*Upper*). Patterns of gum flow from four faces of slash pines. The faces were woodchipped and inoculated on the dates indicated.

FIG. 3 (*Lower*). Cumulative yields of gum from different treatments of faces on longleaf pine.


INOCULATED 1 1/2 INCH BARKCHIPPING
INOCULATED VARIABLE BARKCHIPPING
INOCULATED 3/4 INCH BARKCHIPPING
STANDARD ACID-TREATED
STANDARD WOODCHIPPING
CUMULATIVE YIELD OF GUM IN GRAMS
2600
2200
1800
1400
1000
600
200
4/11/49
5/9
6/6
7/5
8/1
8/29
9/26
10/24

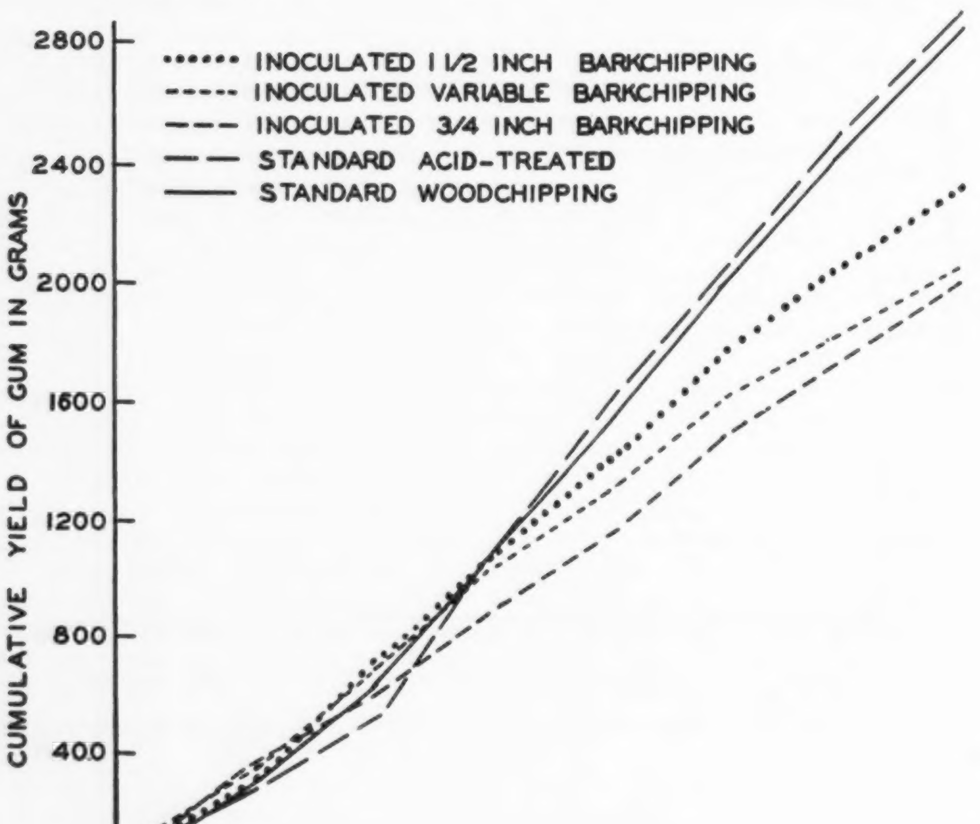

INOCULATED 1 1/2 INCH BARKCHIPPING
INOCULATED VARIABLE BARKCHIPPING
INOCULATED 3/4 INCH BARKCHIPPING
STANDARD ACID-TREATED
STANDARD WOODCHIPPING
CUMULATIVE YIELD OF GUM IN GRAMS
2800
2400
2000
1600
1200
800
400
4/11/49
5/9
6/6
7/5
8/1
8/29
9/26
10/24

TABLE III

YIELDS OF GUM AND SCRAPE FROM INOCULATED DOUBLE WOOD-CHIPPED STREAKS AND FROM INOCULATED BARK-CHIPPED STREAKS ON LONGLEAF PINES FOR A SINGLE SEASON

Streak treatment	Yield of gum per tree	Scrape per tree	Total gum and scrape
	gms.	*gms.*	*gms.*
Inoculated, double wood-chipped; 1 in. high × ½ in. deep, biweekly	2023	397	2420
Inoculated, bark-chipped; 1½ in. high, biweekly ..	1643	397	2040
Check—Standard wood-chipped; ½ in. × ½ in., weekly	1729	703	2432
Check—Acid-treated, bark-chipped; ½ in. high, biweekly	2687	624	3311

TABLE IV

COMPARATIVE YIELDS OF GUM AND SCRAPE FROM INOCULATED AND UNINOCULATED DOUBLE WOOD-CHIPPED STREAKS

Streak treatment	Yield of gum and scrape per tree for one season	
	Longleaf	Slash
	gms.	*gms.*
Inoculated, double wood-chipped; 1 × ½ in., biweekly	2592	4256
Untreated, double wood-chipped; 1 × ½ in., biweekly	1472	2656
Check—Standard wood-chipped; ½ × ½ in., weekly	2336	3553
Check—Acid-treated, bark-chipped; ½ in., biweekly	4704	3328

In 1950 additional tests were made of double wood-chipped streaks, some of which were inoculated with the pitch-canker fungus and others were untreated. The standard wood-chipped and the standard acid-treated streaks were included as checks. A comparison of total yields (Table IV) shows that the inoculated double wood-chipped streaks on longleaf produced 76 percent more gum than the uninoculated streaks, and on slash pine they produced 60 percent more gum than the uninoculated streaks. These figures show the capability of the pitch-canker fungus to stimulate the flow of gum from turpentine pines. However, use of double wood-chipped streaks in the naval stores industry would not be wise when the much more conservative bark-chipping-with-acid treatment has proved so reliable and productive.

Chipping Streaks of Different Heights. A test was made in 1949 to determine the influence of streak height on yields of gum from fungus-inoculated faces. Bark chipping was used, since it is a more conservative treatment than wood chipping, and the results would be more comparable with those of standard acid-treated, bark-chipped faces.

Sixty trees each of longleaf and slash pines were calibrated for gum yields. Trees giving exceptionally high or low yields of gum were not used in the test. Fifty trees of each species were then randomized for five different treatments, giving ten trees per treatment for each species. The treatments used were: inoculated, three-fourth inch chipping; inoculated variable-height chipping; inoculated one and one-half inch chipping; 50 percent sulphuric acid-treated, one-half inch chipping (check); and untreated, one-half × one-half inch wood chipping. The last two treatments are standard practices in the extraction of gum from living turpentine pines. The

FIG. 4 (*Upper*). Cumulative yields of gum from fungus-inoculated streaks of different heights on longleaf pine.

FIG. 5 (*Lower*). Cumulative yields of gum from fungus-inoculated streaks of different heights on slash pine.

variable-height bark chipping involved chipping just above the pitch-soaked wood produced by the preceding inoculated streak, so as to expose clear wood. At the end of the season in 1949 the average height of the variable streaks was nearly one inch. The three-fourth-inch streaks, therefore, did not always expose clear wood.

Cumulative yields of gum from inoculated faces on longleaf (Figure 4) and on slash pine (Figure 5) tended to increase with height of streak. The increased yield of gum from the one and one-half inch streaks may be accounted for by the larger wound that opens up more resin ducts, and by the chipping beyond pitch-soaked wood. Fungus-inoculated faces ultimately yielded considerably less gum than the acid-treated faces. The rates of gum flow for fungus and acid treatments for more than two months, however, were nearly equal.

The less frequently a face is chipped, the longer the tree can be worked for gum. Heights of inoculated faces on longleaf pine (Figure 6) were greater than those on slash pine (Figure 7), since streaks were chipped every two weeks on the former and every three weeks on the latter species. Acid-treated faces had the lowest height—eight inches—for the working season.

Scrape accumulated more rapidly on faces of longleaf than on faces of slash pine (Figures 6 and 7). Acid-treated faces on longleaf pine carried the greatest quantity of scrape per unit area of face, but as a percentage of total gum yield this treatment gave the least scrape. Fungus-treated faces on longleaf carried less scrape per unit area than acid-treated faces, but the percentages of scrape were greater.

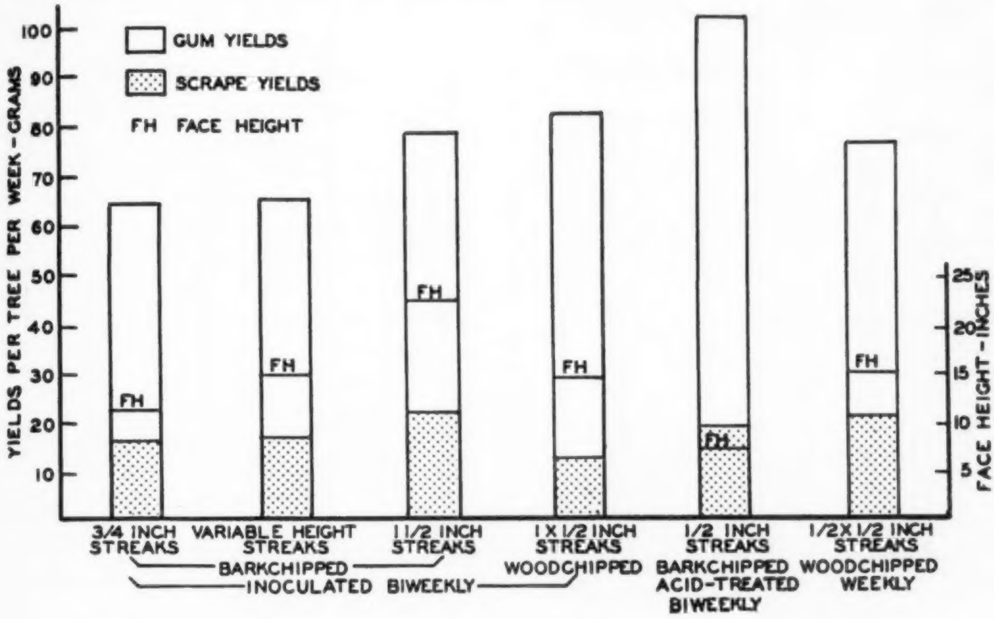
Winter versus Summer Treatments. The standard season for extracting gum from turpentine pines is 32 weeks. Trees are rarely worked during the winter months. With several kinds of treatments available, an investigation was made to determine the relative ability of each treatment to produce gum during the winter season.

The trees in the preceding tests, which included ten trees per treatment and five treatments on both longleaf and slash pines, were used also to compare yields from fungus-treated and acid-treated trees worked during the winter months (1949–50), to compare yields obtained during a regular season (1949) with yields from winter-worked trees, and to note the effects of resting and not resting trees in winter on yields of the following regular season (1950). The ten trees of each treatment were divided into two groups on the basis of their previous regular-season yields so that both groups yielded nearly the same quantity of gum. One group of five trees per treatment was rested for 20 weeks of winter, and the other group was worked during winter.

The winter yields of gum from fungus-treated and acid-treated trees bore about the same relationship to each other as the regular season yields, with yields from acid-treated trees surpassing yields from fungus-treated trees.

The winter yields from all treatments except standard wood chipping were substantially lower than the summer yields (Figures 8 and 9). The average reductions in yield from winter-worked fungus-treated and acid-treated trees of both species of pines ranged from 35 to 40 percent. The reduction in yield of gum from winter-worked standard wood chipping was one percent for longleaf and ten percent for slash pine. This treatment showed promise of profitable use through the winter months; however, its usefulness during that period would depend upon the number of warm days.

Scrape, as a percentage of total gum yield, increased with all treatments on winter-worked longleaf pines, particularly on the wood-chipped faces. Scrape



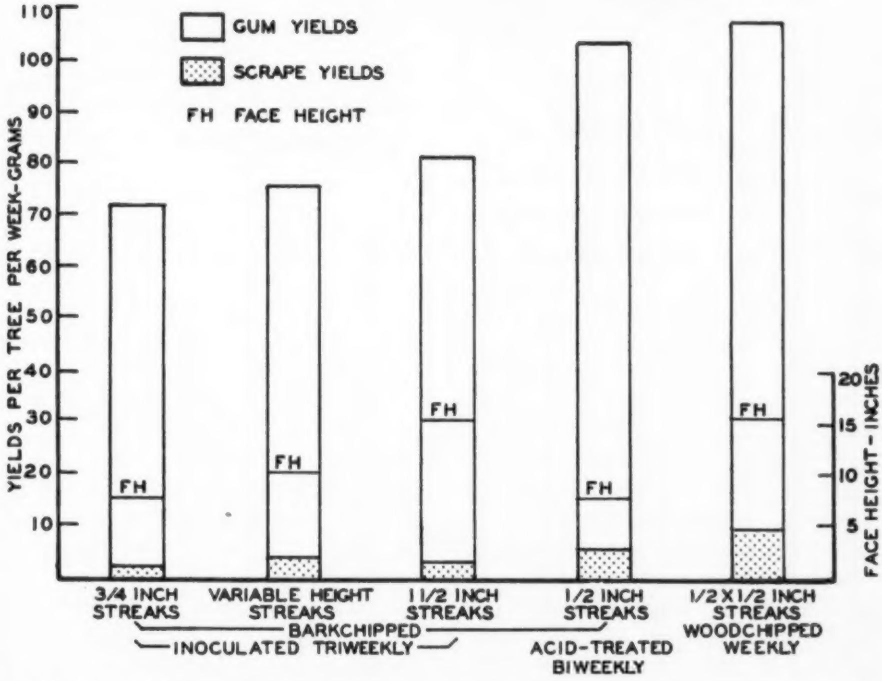
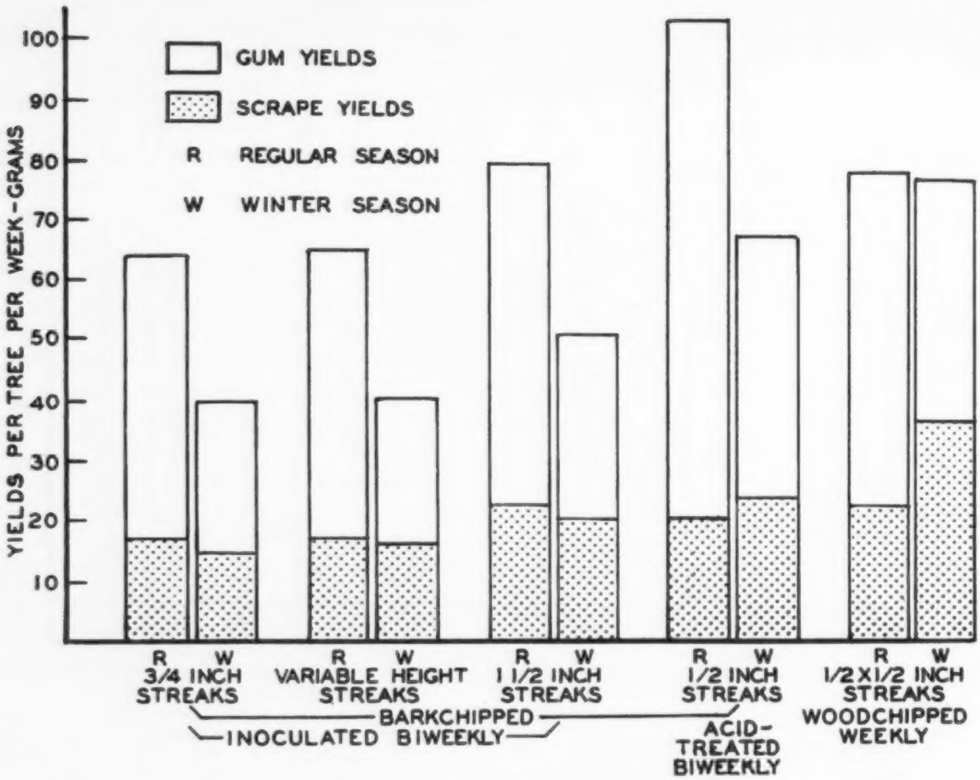
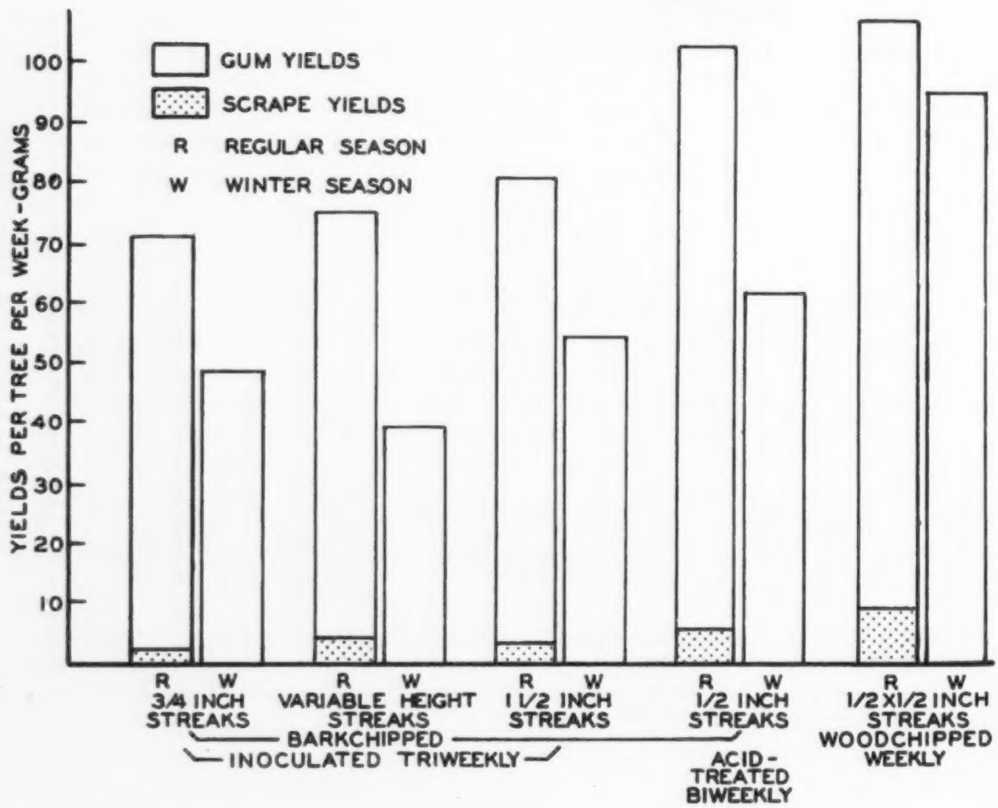


FIG. 6 (*Upper*). Comparative yields of gum and scrape, and heights of faces on longleaf pines receiving different treatments.

FIG. 7 (*Lower*). Comparative yields of gum and scrape, and heights of faces on slash pines receiving different treatments.



GUM YIELDS
SCRAPE YIELDS
R REGULAR SEASON
W WINTER SEASON
YIELDS PER TREE PER WEEK-GRAMS
100
90
80
70
60
50
40
30
20
10
R W
3/4 INCH STREAKS
R W
VARIABLE HEIGHT STREAKS
R W
1 1/2 INCH STREAKS
R W
1/2 INCH STREAKS
R W
1/2 X 1/2 INCH STREAKS
BARKCHIPPED
INOCULATED BIWEEKLY
ACID-TREATED BIWEEKLY
WOODCHIPPED WEEKLY



GUM YIELDS
SCRAPE YIELDS
R REGULAR SEASON
W WINTER SEASON
YIELDS PER TREE PER WEEK-GRAMS
100
90
80
70
60
50
40
30
20
10
R W
3/4 INCH STREAKS
R W
VARIABLE HEIGHT STREAKS
R W
1 1/2 INCH STREAKS
R W
1/2 INCH STREAKS
R W
1/2 X 1/2 INCH STREAKS
BARKCHIPPED
INOCULATED TRIWEEKLY
ACID-TREATED BIWEEKLY
WOODCHIPPED WEEKLY

was negligible on the winter-worked slash pines.

The groups of five trees that were rested during the winter (1949–50) were worked for the regular season of 1950, together with the other groups of five trees that had been worked through the winter. The 1950 regular-season yields of gum from fungus-treated longleaf and slash pines that had been winter-rested and winter-worked were reduced in about the same degree from the 1949 regular-season yield; that is, whether a fungus-treated tree was worked or rested during winter had little effect on yield of gum the following working season (Table V). The 1950 yield from winter-worked acid-treated slash pines equalled the yield of the 1949 season. The 1950 yields of winter-worked wood-chipped longleaf and slash pines were higher than the 1949 season yields.

TABLE V

COMPARISON OF 1950 REGULAR-SEASON GUM YIELDS FROM TREES RESTED AND TREES NOT RESTED DURING THE WINTER OF 1949–50

Face treatment (5 trees per treatment)	Yields of gum per week for 1950 season from: Winter-rested trees	Yields of gum per week for 1950 season from: Winter-worked trees	1949 season yields
	gms.	*gms.*	*gms.*
Longleaf			
Inoculated biweekly:			
¾ in. bark-chipped ...	51	41	65
Variable bark-chipped	45	46	66
1½ in. bark-chipped ..	52	56	79
Check—Acid-treated biweekly	97	76	104
Check—Wood-chipped weekly	76	93	78
Slash			
Inoculated triweekly:			
¾ in. bark-chipped ...	48	54	72
Variable bark-chipped	51	48	76
1½ in. bark-chipped ..	59	57	81
Check—Acid-treated biweekly	92	104	103
Check—Wood-chipped weekly	84	111	108

Treatments on First and Last Streaks. In 1951, tests were made on longleaf and slash pines to determine the increase in yields of gum that would be obtained by inoculating the first and last streaks of the season on standard acid-treated and standard wood-chipped trees. Ten trees were used for each treatment and each check. The trees were calibrated for gum yields prior to the tests, and those yielding excessively high or low were discarded. The first test, which started on February 1, six weeks before the regular gum season, ran for 38 weeks.

Inoculated first and last streaks on acid-treated faces yielded insufficient amounts of gum to raise the total yields to those obtained from the acid-treated check trees (Table VI, Part I). Furthermore, the acid-treated streaks on longleaf pine yielded at the rate of 12.0 barrels of gum per streak, and on slash pine at the rate of 10.5 barrels, compared with 4.3 barrels per fungus-inoculated first and last streaks on longleaf, and 7.0 barrels per fungus-inoculated first and last streaks on slash. Therefore, total yields of gum in these groups of trees would probably have been higher if all the streaks had been acid-treated.

The inoculated first streak only on wood-chipped trees yielded at a higher rate than that obtained from either inoculated first or last streak on bark-chipped trees. The uninoculated wood-chipped streaks yielded at the rate of 3.3 barrels of gum per streak for longleaf and 3.8 barrels per streak for slash pine,

FIG. 8 (*Upper*). Comparison of gum and scrape yields from longleaf pines worked for a regular season and from trees worked during winter.

FIG. 9 (*Lower*). Comparison of gum and scrape yields from slash pines worked for a regular season and from trees worked during winter.

TABLE VI

GUM YIELDS FROM INOCULATED FIRST AND LAST STREAKS OF THE SEASON, AND FROM ACID-TREATED AND WOOD-CHIPPED STREAKS ON LONGLEAF AND SLASH PINES

Streak treatment	Yield of gum from Longleaf		Yield of gum from Slash	
	Per tree	Per crop [1]	Per tree	Per crop [1]
	gms.	*bbls.*[1]	*gms.*	*bbls.*
		Part I [2]		
Bark chipped				
Inoculated first streak	113	5.7	137	6.9
Biweekly acid-treated streaks	4044	204.6	3315	167.7
Inoculated last streak	56	2.8	141	7.1
Scrape	1242	62.8	363	18.4
Total yields	5455	275.9	3956	200.1
Check—Biweekly acid-treated streaks	4293	217.2	4419	223.6
Scrape	1225	62.0	544	27.5
Total yields	5518	279.2	4963	251.1
Wood chipped				
Inoculated first streak	207	10.5	249	12.6
Weekly wood-chipped streaks	2241	113.4	2402	121.5
Inoculated last streak	56	2.8	110	5.5
Scrape	1196	60.5	550	27.8
Total yields	3700	187.2	3311	167.4
		Part II [3]		
Bark chipped				
Inoculated first streak	87	4.4	139	7.0
Biweekly acid-treated streaks	2999	151.7	3431	173.6
Inoculated last streak	54	2.8	120	6.1
Scrape	936	47.4	470	23.8
Total yields	4076	206.3	4160	210.5
Check—Biweekly acid-treated streaks	3711	187.8	3323	168.1
Scrape	1038	52.5	301	15.2
Total yields	4749	240.3	3624	183.3
Wood chipped				
Inoculated first streak	157	7.9	248	12.5
Weekly wood-chipped streaks	1818	92.0	2634	133.3
Inoculated last streak	75	3.8	159	8.0
Scrape	1055	53.4	386	19.5
Total yields	3105	157.1	3427	173.3
Check—Weekly wood-chipped streaks	2065	104.5	2752	139.2
Scrape	1087	55.0	357	18.1
Total yields	3152	159.5	3109	157.3
Check—Wood-chipped streaks, inoculated weekly	2178	110.2	3327	168.3
Scrape	1157	58.5	510	25.8
Total yields	3335	168.7	3837	194.1

[1] One standard barrel of gum weighs 435 pounds; a crop is 10,000 trees.
[2] This test began February 1, 1951, and continued for 38 weeks.
[3] This test began with the regular gum season, April 4, 1951, and continued for 32 weeks.

significantly less than the yield from the inoculated first streak on longleaf, 10.5 barrels, and on slash pine, 12.6 barrels.

The second test of inoculating first and last streaks began with the regular gum season, April 4, and continued the customary 32 weeks. The first and last streaks of the season on both acid-treated and wood-chipped trees were inoculated with the pitch-canker fungus. The checks were standard acid-treated and standard wood-chipped trees. The test also included ten trees each of longleaf and slash pines that received the standard weekly wood chipping, with weekly inoculations of the streaks.

The inoculated streaks on acid-treated faces of slash pine yielded additional gum at the rate of 13.4 barrels per crop, bringing the total yield up to 210.5 barrels, compared with 183.3 barrels obtained from the acid-treated check (Table VI, Part II). However, the acid-treated streaks yielded at the rate of 13.1 barrels of gum per streak, whereas the inoculated streaks yielded at the rate of 6.6 barrels per streak. Here, as in the preceding test, the total yield of gum would probably have been higher if all streaks had been acid-treated. Inoculation of streaks on acid-treated faces of longleaf pine failed to raise the total gum yield to that of the uninoculated trees.

Yields from inoculated first and last streaks on wood-chipped faces surpassed yields from the inoculated streaks on bark-chipped acid-treated faces, and again they were significantly higher than yields of uninoculated wood-chipped streaks.

Standard wood chipping with the streaks chipped and inoculated weekly gave substantial increases of gum over weekly uninoculated wood chipping, especially on slash pine, where the increase was at the rate of 37 barrels per crop.

The foregoing tests show that inoculated first and last bark-chipped streaks on acid-treated faces yielded gum at a significantly lower rate per streak than the acid-treated streaks. Inoculated first and last wood-chipped streaks on wood-chipped faces yielded gum at a significantly higher rate per streak than uninoculated wood-chipped streaks. The rate of gum production of inoculated wood-chipped streaks over inoculated bark-chipped streaks is probably due to the deeper wounding made by wood chipping.

South Florida Slash Pine. The south Florida slash pine occurs along the coasts of Florida as far north as Daytona Beach and Tampa and up to Okeechobee County. This species has not been exploited much for its gum, although the stumps are collected for extraction of naval stores. Tests were started on May 4, 1951, on pines of The Atlantic Land and Improvement Company, near La Belle, Florida, to determine the gum yield from bark-chipped faces, chipped and inoculated with the pitch-canker fungus, triweekly, and from standard acid-treated faces, chipped and treated biweekly. The fungus used in this test was an isolate of *Fusarium* from a pitch canker on a south Florida slash pine. Since the trees were not calibrated for gum yields, 20 instead of ten trees were used per treatment. The trees ranged from ten to 14 inches d.b.h. Average streak height on fungus-treated faces was one and one-fourth inches, and on acid-treated faces one inch.

The average yield of gum per tree per week for the 32-week season from the fungus treatment was 55 grams, compared with 81 grams obtained in 1949 from the common slash pine in north Florida that was chipped at about the same height. The gum yield from acid treatment was 91 grams, compared with 98 to 104 grams obtained in tests on the common slash pine. Scrape on the La Belle trees was not collected. Acid-

treated trees of south Florida slash pine carried considerably more scrape than the fungus-treated trees; therefore, the total yield of gum from the acid treatment probably would have equalled the yield from the acid-treated common slash pines.

Pitch Soaking. Pitch-soaked wood in its commonest natural form occurs in heartwood stumps of virgin longleaf pine. The stumps are of little value and usually a nuisance to the farmer, but the pitch-soaked wood is of commercial value to the naval stores industry which distills or extracts turpentine and other products from it. The supply of these stumps is diminishing with little or no replacement. The heartwood of trunks of south Florida slash pine is also pitch-soaked, and farmers use the wood without further preservative treatment for fence posts.

A marked characteristic of infection by the pitch-canker fungus (*Fusarium lateritium* f. *pini*) is a pitch soaking of the wood of Virginia pine and the turpentine pines (Figure 1, B). Pitch soak behind fungus-inoculated faces on the trunks of turpentine pines, however, extended radially usually to a depth of only one-half inch, and in some instances deeper. The volume of pitch-soaked wood behind these faces has been insufficient for use as distillation or extraction wood.

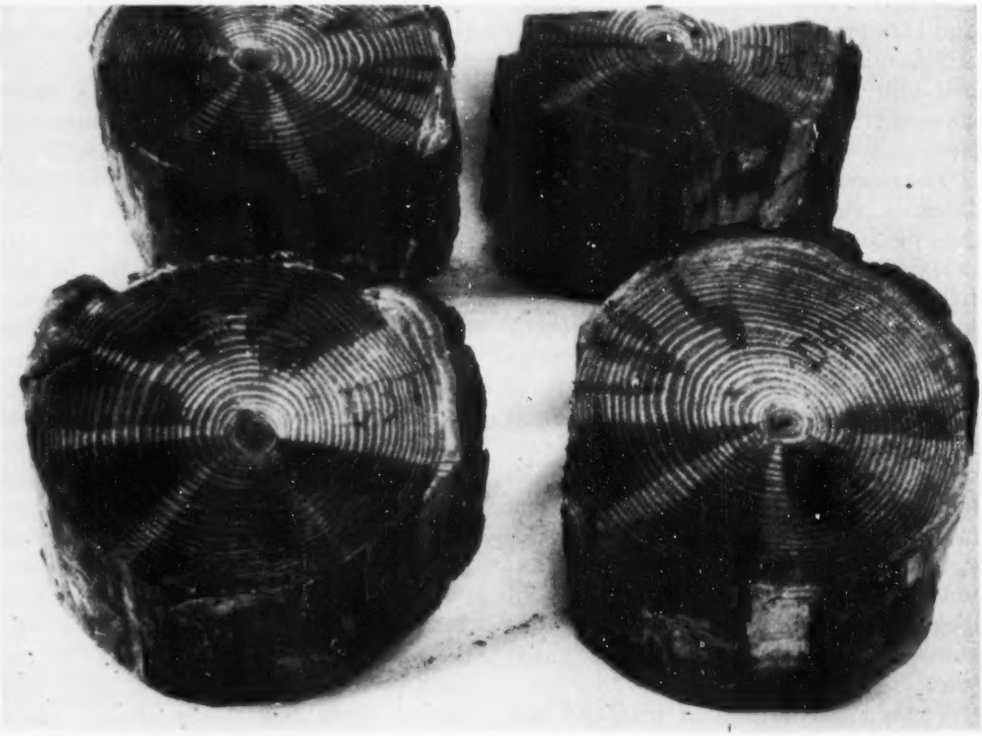


FIG. 10. Distribution of pitch soak behind inoculated hatchet cuts on the trunk of a slash pine.

A number of attempts were made to increase the volume of pitch-soaked wood in the trunks of turpentine pines, with the objectives of using the trunk wood as durable posts and as a source of naval stores. Different types of wounds, including long, vertical streaks, multiple hatchet or ax cuts, and peeled faces on trunks of longleaf and slash

pines, were inoculated with the fungus to induce pitch-soaking of the wood. Thus far treatment with multiple hatchet cuts appears to be promising (Figure 10), but more extensive tests are needed.

Other Tests. Investigators frequently punch holes in the bark of pine trunks to determine relative yields of gum after using various agents on the wounds (4). Replicated tests can be made on a single tree where variations in yields between similarly treated wounds usually are less than variations obtained from different trees.

Punch-hole tests were made on slash pines during the period **1949–51** to determine gum yields from the use of various isolates and metabolic substances of the pitch-canker fungus. Tests made to determine the influence of age of culture on yields of gum showed that an isolate of the fungus subcultured several times for one year was as effective as a fresh isolate for producing gum flow. Two mutants of *Fusarium lateritium* f. *pini* stimulated greater gum flow than the parental isolates. Further investigation of mutants of this fungus might be worth while. Other tests showed that gum yields tended to be higher as the concentration of spores suspended in water increased; a water suspension of spores aged for 30 days at room temperature loses its stimulating properties; and the property of stimulating gum flow is lost if a liquid culture is autoclaved, centrifuged or passed through a Jenkins filter to remove the spores, as tested by spraying the fungus-free culture solutions on punch wounds.

In other tests, various derivatives from cultures of this form of *Fusarium* were used to treat punch-hole wounds. Small amounts of metabolic substances were obtained from the liquid substrates on which the fungus had grown for six weeks. The substrates were filtered to remove the spores, evaporated in vacuum at 95° F., and the residues were mixed with various hydrocarbon solvents. Also, ether and alcoholic extractions were made from the mats produced by the fungus on liquid media. All these agents, when applied to punch-hole wounds, produced an insignificant flow of gum.

Discussion

The property of the pitch-canker fungus to stimulate the flow of gum from certain species of pines is unique. The fungus was thoroughly investigated with respect to this property to determine whether it could be used commercially. The fungus, when inoculated into faces on slash and longleaf pines, consistently stimulated a flow of gum equivalent to that from acid stimulation for the first few weeks. Yields from the fungus treatment thereafter invariably diminished.

Two mutants of the fungus produced higher yields of gum than the parental isolates, but were not investigated. Mutants of other fungi used in commerce have increased the efficiency of production of various by-products, and there is a possibility that mutants of the pitch-canker fungus could be produced that would boost the yields of gum obtained from inoculated faces.

At the present time, acid stimulation gives higher and more dependable yields of gum than any of the fungus treatments tried, and its use is steadily increasing in the naval stores industry.

Pitch soaking the wood of turpentine pines by inoculating particular types of wounds with the pitch-canker fungus is undergoing investigation.

Summary

The pine pitch canker, caused by *Fusarium lateritium* f. *pini*, occurs throughout the southeastern States and attacks the branches and young stems of Virginia pine (*Pinus virginiana*), slash pine (*P. elliottii*), south Florida slash pine (*P. elliottii* var. *densa*) and long-

leaf pine (*P. palustris*). Exudation of oleoresin and pitch-soaking of the wood are usually associated with the cankers.

A water suspension of spores of the fungus, when inoculated into virgin streaks of faces on turpentine pines, prolonged the flow of oleoresin in substantial amount from longleaf pine to three weeks, and from slash pine to five weeks. Rechipping and reinoculating prolonged the flow of oleoresin from longleaf to two weeks and from slash pine to three weeks. Untreated streaks flowed oleoresin one week. No typical cankers developed on the trunks of turpentine pines following inoculation of the streaks with the pitch-canker fungus.

Yields of oleoresin from inoculated faces usually equalled those from standard sulphuric acid-treated faces for the first month or six weeks, then declined, so that the season's yield of oleoresin from fungus stimulation seldom equalled that from acid stimulation. Depth of pitch soak behind inoculated faces extended usually about one-half inch and in some instances one and one-half inches. Greater depths of pitch soaking occurred when the trunks were wounded by downward cuts made with a hatchet, and the wounds were inoculated with the fungus. Investigations on methods of inducing pitch soaking of turpentine pines by inoculations with the pitch-canker fungus are continuing.

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Utilization Abstract

Hemlock Tannin. Consumption of eastern hemlock bark from Michigan and Wisconsin as a domestic source of tannin fell from an estimated high, in the past 25 years, of 63,000 cords in 1928 to some 4,400 cords in 1951. This decline occurred despite the 80% dependence of the American tanning industry on foreign sources of tannin, a situation which has directed attention to the relatively new tannin sources in scrub oaks of Florida, mixed oaks of the Tennessee Valley, canaigre root from the Southwest and the barks of western hemlock, Douglas fir, spruce and redwood.

Over 70% of the hemlock cut in the eastern U. S. today comes from the forests of northern Michigan and Wisconsin. Despite the estimated 1,200 million cubic feet of forest hemlock still standing in those two States, use of the bark as a source of tannin is still decreasing. "The main reason for this decline is that cost-conscious tanners have been able to secure other tanning materials at their plants for a lower cost per ton unit (1 pound of 100 per cent tannin) than from hemlock bark". Investigations directed toward increasing the use of this domestic material have considered the advisability of producing liquid or powdered extract of the bark in the Upper Peninsula of Michigan. (N. F. Roger, W. H. Koepp and E. L. Griffin, *Jour. Am. Leather Chem. Soc.* *49*(*2*): *75. 1954*).

Utilization Abstracts

Tannin from North Borneo. In 1951 North Borneo produced 90,270 hundredweight of mangrove tannin extract from the bark of species of *Ceriops* and *Rhizophora*, 75% of which was sent to the United States. (*Colonial Plant and Animal Products 3: 53. 1952–1953*).

Tannins of India. The following indigenous species of India are used or have been investigated as commercial sources of tannin:

Babul fruits (*Acacia arabica*)
Dhemdal bark (*Carapa obovata*)
Garjan bark (*Rhizophora acutangulata*)
Haritaki fruits (*Terminalia Chebula*)
Haritaki bark (*Terminalia Chebula*)
Hopea bark (*Hopea parviflora*)
Keora bark (*Sonneratia apetala*)
Khair heartwood (*Acacia Catechu*)
Matgoran bark (*Ceriops roxburghiana*)
Passur bark (*Carapa moluccensis*).
Small goran bark (*Ceriops candolleana*)
Sonalu bark (*Cassia fistula*)
Sundri bark (*Heritiera minor*)

(Sarkar, P. K., *Tanner 7(1): 17; (3): 15; (4): 15; (5): 15. 1952*).

Acacia Tannin. Pods of *Acacia arabica* offer an important tanning material in African countries, and the bark of the same species constitutes the principal tanstuff of northern India. The plant is a moderate sized, almost evergreen tree, indigenous to large areas of Africa and Asia, but has not found much use as a source of tannin outside these regions. The pods were used for tanning as early as Pliny's time, and both bark and pods have since been known under a variety of names, some of which are: babla (Arabic), babul (Hindustan), bahar (Sind), sant or sunt grains or garad pods (Sudan), gonaike or neb-neb (French West Africa), gabaruwa or bagaruwa (Nigeria).

Indian pods, from which the seeds have been removed, contain 18–27 percent tannin, but Sudanese material has 30 percent or more. The bark, containing about 12 percent tannin, has constituted the most important tanning material in northern India, being employed usually in small village tanneries. The annual bark requirements for northern India were about 100,000 tons annually up to 1940, but since that time wattle extract has been supplementing babul. (W. D. Raymong, *Colonial Plant and Animal Products 2: 285. 1951*).

Industrial Raw Materials of Plant Origin. V. A Survey of the Bamboos. This, the largest and latest of a series of publications noted in previous issues of ECONOMIC BOTANY, is a comprehensive review of more than 1,000 citations on the industrial utilization, actual and potential, of bamboos throughout the world, but with special attention directed toward their cultivation and possible uses in the United States.

According to the rather inadequate classification of them which has so far been formulated, between 500 and 1,000 species of bamboo are known, ranging in size at maturity from about six inches (e.g., *Arundinaria pygmaea* of Japan) to 70 feet or more (e.g., *Phyllostachys bambusoides* of China and Japan) and widely distributed in many parts of the world—China, Japan and India, the East Indies, parts of Africa and of South America. Over this extensive area their " uses are almost infinite. In the Orient, particularly, it is said that most human needs other than food can be supplied by bamboo, and the young shoots of many species are esteemed, fresh or preserved, as a vegetable food. The larger species are used for structural purposes, furnishing shelter, weapons, bridges, water pipes, etc. Still other species are suitable for cutting into strips of varying sizes to be used for weaving a type of coarse cloth, bags, baskets, and other items ". Various species have been and are being used in the manufacture of paper in many countries—Argentina, China, Germany, India, Indo-China, Venezuela, Siam—but only in India, where about 80,000 tons of bamboo pulp are used annually, has such utilization attained the status of a major industry. In China, however, one large use of bamboo pulp has been in the manufacture of tin-coated joss paper used for smoke sacrifices

at religious and family celebrations. In the Yangtze valley the sales of joss paper have amounted to $3,927,000 in one year.

In the United States only two species of bamboo are known to occur naturally, the giant southern cane (*Arundinaria gigantea*) and switch cane (*A. tecta*), but efforts have been made to raise exotic species in order to meet the demand for bamboo which is now being filled primarily by imported material. The United States Department of Agriculture operates the Barbour Lathrop Plant Introduction Garden on the Ogeechee River, near Savannah, Georgia, and experiments on about 175 species have been carried on there. More than 35 of them are now commercially available from nurseries, and many of them are being grown in Alabama, Florida, Georgia, Louisiana, Mississippi, South Carolina, Texas and the eastern parts of North Carolina and Virginia.

A market already exists in the United States for all types of bamboo furniture and household ornaments, as well as for bamboo rug poles and fishing poles. The bulk of the bamboo imported into this country in the form of untreated sticks consists of canes for unmanufactured fishing poles, almost exclusively *Phyllostachys aurea* ("fishpole bamboo") but including also some *P. bambusoides*), and of canes for the manufacture of laminated fishing rods and for use as rug poles and handling poles, most of which is Tonkin cane (*Arundinaria amabilis*). The future annual domestic market for bamboo in these and many other uses is estimated to be between 1¼ and 1½ million dollars. (H. H. Sineath, P. M. Daugherty, R. N. Hutton, T. A. Wastler, *Ga. Inst. Tech., State Engin. Exp. Sta., Bull. 15(18)*; also marked "*Bulletin No. 18*". *1953*).

Canaigre Tannin. The United States tanning industry is dependent upon foreign sources for about 85% of its tannin, and about 85% of the domestic supply comes from blight-killed chestnut trees; the balance mostly from oak and hemlock bark, sumac leaves and pecan shells. Canaigre roots contain 25–35% tannin, and some practical use has been made of them, but they have not yet been established as a commercial source. The best growing areas for the shrub are in Arizona, Nevada, California and Utah, and improved strains are being developed. (J. S. Rogers and L. M. Pultz, *Shoe and Leather Rep. 268* (*13, 20*). *1952*).

Luffa Gourd. For centuries the gourds of *Luffa*, especially of the species *L. cylindrica* and *L. acutangula*, have been a well established crop in Japan where they have been utilized in various ways. Incisions made in the stem yield a clear liquid regarded in Japan as having medicinal value, especially in respiratory diseases, and as suitable for use in cosmetic preparations. The fruits are edible and in some parts of Japan form a regular part of the native diet. And the seeds yield an oil, small quantities of which at one time were used in the soap industry of the United States.

The real economic importance of luffa gourds today lies, however, in the mesh of fibrous network which permeates the entire fruit and which is freed from surrounding tissue by fermentation in running water and by a variety of other ways. After drying and bleaching, these fibrous skeletons are utilized in a variety of ways, namely, as sponges and in the manufacture of bath-gloves, pad-straps, shoe insoles, wipers for cleaning cars, and as filters for marine engines. (Miss J. S. Ingram, *Colonial Plant and Animal Products 3*(*2*): *165*. *1952–3*).

Lime Oil. Lime oil is obtained at present by four methods: *a*) Hand pressure, used only in the West Indies, yields oils of the finest quality. "Owing to the high cost of production, only very small quantities are produced, the oil being used mainly in the manufacture of fine perfumery and high-class toilet products. It has a soft and lasting flavour, especially suitable for confectionery, although for boiled sweets many manufacturers prefer the distilled oil, which has a sharp and fresh note".

b) Machine pressure, used in U.S.A. and Mexico, yielding a grade of oil very inferior to the preceding.

c) Distillation of crushed fruit, producing by far the bulk of the world's supply.

d) Distillation of waste peels after most of the oil has been expressed. This is a new and as yet unestablished technique. (E. B., *Colonial Plant and Animal Products 3*(*3*): *255*. *1952–3*).

BOOK REVIEWS

Poisonous Plants of India. Ram Nath Chopra, Rattan Lall Badhwar and Sudhamoy Ghosh. Vol. I. liv + 762 pages. Publ. by the Indian Council of Agricultural Research, New Delhi, India. 1949. Rs 30/–.

Over 2,000 medicinal and poisonous plants are known to be indigenous to India. In 1949 Volume I of this monograph was published, with plans for one or more succeeding volumes. ECONOMIC BOTANY has belatedly become aware of this significant undertaking, the size of which, as well as its quality, justifies attention being called to it at this late date.

In the words of the preface to this work, "it has been the dominant object of the authors to furnish the readers with a complete outline of the botanical, chemical, pharmacological, and economic aspects of poisonous plants dealt with in this work, especially from the point of view of their practical importance. The monograph has been profusely illustrated and deals with about 700 plants poisonous to man, livestock, insects and fishes, their vernacular names, botanical descriptions, distribution and economic aspects, and, where known, important chemical constituents and physiological action, the symptoms produced by them and the lines of treatment and prevention of poisoning".

Not all the plants specifically treated as native to India are of commercial importance, but under the accounts of families, "a general survey has been attempted of the poisonous plants of the whole world, their salient properties and chemical constituents". And with each species, in addition to the general account concerning it, an attempt has been made to give an exhaustive list of vernacular names. A glossary of botanical terms and a 93-page introduction dealing with many aspects of poisonous plants in general, supplement the 668 pages devoted to families, genera and species.

To choose some one part from these latter pages for citation and discussion as representative of the work as a whole defies the selective ability of the present reviewer. Those pages contain such a mass of information on the economic importance not only of poisonous plants in India but also of a great many other plants throughout the world, that it suffices to state that this work, published by the Indian Council of Agricultural Research, together with the several-volume "Wealth of India" being published at intervals by the Indian Council of Scientific and Industrial Research, will provide, when completed, a storehouse of relatively up-to-date information on the economically important plants of India such as has not been published for any other country since Burkhill's "A Dictionary of the Economic Products of the Malay Peninsula" appeared in 1935.

The Story of Spices. John W. Parry. viii + 208 pages. Chemical Publishing Co. 1953. $4.50.

Every school child learns, presumably, that Columbus discovered America as a result of his effort to find a new route to the Indies, the land of spices, but the full significance of that statement, very likely, is appreciated by few. The importance lies in the fact that for two or three hundred years, beginning about five centuries ago, spices were of such great importance to the peoples of Europe that efforts to obtain them led to the greatest period of exploration the world has ever known, and to wars between nations contending for control of routes to the sources of spices, once they were found. Other groups of plants—food plants, drug plants and timber trees, to mention only three—have been of greater importance for the welfare of mankind, but none of them had the world-wide influence on the political destinies of man as did spices. References to this role of spices are abundant in the popular literature on economically important plants, but nowhere, at least in recent years, has the story been brought together and so admirably presented in delightful reading style as in this book. Strictly botanical information

has been deliberately omitted, and even in the Appendix, which lists and gives brief descriptions of some 40 spices, there is not a single scientific name. The only reason given for the omission is "for the sake of simplicity", and one wonders why, in spite of this reason, the spices are grouped into scientific plant families. Surely the relationships of spices so that they fall into particular plant families is not at all apparent to a reader who is not interested in botanical names, and they mean nothing to him. An alphabetical listing of the spices, without regard to families, would suit the purpose just as well, and would be in harmony with the idea of "simplicity". This is a very minor point of criticism and is not made with any disparaging intention, but, rather, as an expression of the present reviewer's disappointment that he will not be able to refer to his copy of this otherwise excellent volume as an authoritative source of information regarding scientific names and perhaps a few other technical data, such as regarding areas of commercial production today, which would have necessitated, perhaps, not as many as six additional pages.

The 180 pages of this book devoted to the historical story of spices is without criticism, unless some astute and pedantic archivist finds reason to disagree with some historical detail. It begins with accounts of spices in the ancient world and in the times of the Holy Bible, emphasizing the great importance of cassia and cinnamon in those days. Perhaps the most interesting detail of that early utilization of these plant products for embalming the dead and in religious ceremonies, was the fact that the Assyrians, the Babylonians and the Egyptians who used them did not know whence they came, and that the wily Arabian spice merchants who brought the spices, concocted all sorts of weird tales regarding their origins in order to withhold all information about the true sources—Ceylon, India, Cochin-China and the East Indies.

The Arabian monopoly in the spice trade was broken by the Portuguese in the Age of Exploration in the fifteenth and sixteenth centuries; and the Portuguese were succeeded, in turn, by the Dutch and the English. Each succession involved intrigue and war, bloodshed and other hardship, and finally mastery of the sea lanes, all for the purpose of delivering the spices to the East—cinnamon, nutmeg, cloves, cassia and others—to the markets of Europe. These were not minor events; they were world-shaking projects, all because of a few plant products which were in demand to make food more palatable in the days before mechanical refrigeration, to embalm the dead of Egyptian dynasties and to bring riches to royal coffers from Solomon to the Princes of Europe.

Nowhere else in recent literature has this tale been so interestingly related as in "The Story of Spices".

Seaweed Utilization. Lily Newton. xii + 188 pages. Sampson Low, 25 Gilbert St., London W1, England. 1951.

Although three years late, ECONOMIC BOTANY would be remiss if, despite this tardiness, it did not call attention to this book which is commendable not only because of its text but especially in view of its 74 excellent plates. Many of the latter are reproductions of prize-worthy natural life photos, and all of them contribute toward this well illustrated volume on the economic importance of the plants of the sea.

After an introductory chapter on the biology of seaweeds, there follow others on the former uses of these weeds in agriculture and as industrial sources of soda, potash and iodine. Production of alginates in Great Britain, France, Norway, Russia, Australia, South Africa, U.S.A., Chile and Japan is followed by a chapter on rayon manufactured from alginic acid. Seaweeds as human food and the extracts agar and carrageen, as well as related other aspects of the subject, receive their merited attention.

The only criticism which can be made of this book, so far as its make-up is concerned, is that it lacks an index, the need for which is not at all met by the table of contents. The result is that, while the book provides excellent reading and illustrations on the subject, it is not very satisfactory as a reference work, unless one is inclined to examine entire chapters for their possible content of particular bits of information sought.